Integrating technology in the classroom: a visual conceptualization of teachers’ knowledge, goals and beliefs

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Abstract
In this paper, we devise a diagrammatic conceptualization to describe and represent the complex interplay of a teacher’s knowledge (K), goals (G) and beliefs (B) in leveraging technology effectively in the classroom. The degree of coherency between the KGB region and the affordances of the technology serves as an indicator of the teachers’ developmental progression through the initiation, implementation and maturation phases of using technology in the classroom. In our study, two teachers with differing knowledge, goals and beliefs are studied as they integrated GroupScribbles technology in their classroom lessons over a period of 1 year. Our findings reveal that the transition between the teacher’s developmental states (as indicated by coherency diagrams) is nonlinear, and thus the importance of ensuring high coherency right at the initiation stage. Support for the teacher from other teachers and researchers remains an important factor in developing the teacher’s competency to leverage the technology successfully. The stability of the KGB region further ensures smooth progression of the teacher’s effective integration of technology in the classroom.

Keywords
teacher change, technology in the classroom, technology integration.

Introduction
There is much consensus that technology is now an inevitable and integral part of our everyday life, work and home experiences. Concomitantly, the call for schools to move to a more technologically integrated approach to teaching and learning has been resonating among ministries or departments of education in various countries. It is an undeniable fact that teachers play a central role in integrating technology in the classroom. In our previous paper (Chen & Looi 2008), we have argued that the coherency between a teacher’s knowledge, goals and beliefs, i.e. ‘KGB’ and the affordances of the technology is the main key in leveraging technology successfully in the classroom. By viewing the teacher’s developmental trajectory through the three phases of initiation, implementation and maturation, we explore the different interplay mechanisms between a teacher’s KGB and the affordances of the technology.

In this paper, we investigate the different knowledge, goals and beliefs of two teachers in a primary (elementary) school as they integrate a technology called GroupScribbles (GS) in their lessons that seeks to employ collaborative and constructivist pedagogies based on the concepts of Rapid Collaborative Knowledge Building (DiGiano et al. 2006). In addition, we have devised representations of ‘KGB diagrams’ and coherency diagrams to better illustrate the complex interplay of teacher’s knowledge, goals and beliefs in their developmental trajectories as they developed their competencies in using the technology in the classroom. At the end of this comparative study, we make some
notable assertions from our research and draw some recommendations for helping teachers integrate technology more effectively in the classroom.

**Literature review**

Various research works have established that teachers’ beliefs play an important role in influencing teachers’ instructional decisions and classroom practices (Cohen 1990; Pajares 1992; Calderhead 1996; Ertmer 1999, 2005). Aguirre and Speer (2000) argues that beliefs play a central role in a teacher’s selection and prioritization of goals and actions in her teaching. Moreover, beliefs shape how teachers perceive and interpret classroom interaction which influences their responses and decision-making processes in the classroom.

With the view that teacher’s beliefs have a profound impact on teaching practices, a series of studies has been done to investigate the relationships between a teacher’s beliefs and technology use in classroom. Ertmer (1999) describes two barriers to technology integration, namely, first-order barriers and second-order barriers. Second-order barriers are intrinsic to the teacher and they include teachers’ beliefs which are harder to overcome than first-order extrinsic barriers such as lack of access to software, support and time. Therefore, the teacher’s beliefs have to be addressed adequately first in order to have meaningful technology integration. Extending from this, Becker (2000) and Niederhauser and Stoddart (2001) indicate that teachers who hold more constructivists beliefs tend to use technology more often than those who held more teacher-centred beliefs.

The research of Schoenfeld (1999, 2006) shows that it is not only the teacher’s beliefs but the teacher’s knowledge and goals that play an important role in every pedagogical decision that the teacher makes. In developing a comprehensive model of the teacher’s decision-making process, Schoenfeld (1999) considers ‘how goals, beliefs and knowledge serve to select and shape courses of action taken by the teacher.’ The teacher’s knowledge, goals and beliefs influence each other in a complex manner in every decision process embarked on by the teacher in the classroom. This forms the underlying architecture behind the TMG’s (Teacher Model Group) model. The basic idea is that a teacher’s decision-making and problem solving is a function of the teachers’ knowledge, goals and beliefs (Schoenfeld 1999, 2006).

Schoenfeld and the Teacher Model Group have utilized the TMG model in analysing, explaining and diagnosing many complex and widely varying teaching episodes (Arcavi & Schoenfeld 1992; Schoenfeld 1999; Schoenfeld et al. 2000) at multiple grain sizes. The model has thus proven to be robust (Schoenfeld 2006). However, there seems to be little work on the complex interplay of the teacher’s knowledge, beliefs and goals related to the integration of IT in the classroom in the TMG model. In this study, we seek to explore these issues further using the KGB diagram and coherency diagram mechanisms.

**Visual conceptualization**

**The KGB diagram**

In seeking to represent the complex interplay between teachers’ knowledge, goals and beliefs or ‘KGB’, we have devised the ‘KGB diagram’ (Fig 1). In our study, the teacher’s beliefs (B) refer specifically to the epistemological beliefs of the teachers. In other words, these beliefs concern teachers’ views about the nature of knowledge and how knowledge is learned (Hofer & Pintrich 1997). These conceptions of knowledge impact the teaching practices of a teacher (Brownlee et al. 2002). Goals (G) are what a teacher sets to accomplish in class (Schoenfeld 1999). These goals can be intrinsic to the teacher and coherent with her beliefs, or they can be extrinsic to the teacher and imposed upon her by the school, community, or other stakeholders. The knowledge of a teacher (K) includes content knowledge, pedagogical content knowledge and knowledge of the students (Bransford et al. 2000).

![Fig 1 KGB diagram.](image-url)
In the Mentored and Online Development of Educational Leaders in Science program that supports teachers’ professional development to implement technology-enhanced inquiry instruction, these knowledge components (content knowledge, pedagogical content knowledge and knowledge of students’ learning) have been identified as core areas of teachers’ knowledge enhancement (Lee & Spitulnik 2008). The theoretical framework of designing these professional development activities is founded on the Knowledge Integration (KI) framework (Linn 2000, 2006; Slotta & Linn 2000). Some activities include connecting teachers’ existing knowledge about teaching with new ways of teaching with technology (Davis 2004) and scaffolding teachers to make their own thinking visible via interacting with their peers through a forum (Lee & Spitulnik 2008).

The ‘KGB diagram’ represents teacher beliefs (B), goals (G) and knowledge (K) as separate circular set representations. Each region in the KGB diagram is contextualized with respect to a specific situation in the classroom where a teacher’s K, G and B are brought to bear in her teaching, shaping her intentions, interactions and other decisions she has to make. In Fig 1, we have divided the KGB diagram into eight regions for clarity of explanation. Regions 1, 2 and 3 denote the intersection of two circular sets, regions 4, 5, and 6 denote no intersection while region 7 denotes the intersection of all three circular sets.

Region 1 represents the intersection between teacher’s knowledge and teacher’s beliefs. It denotes a classroom situation where the teacher applies selected knowledge that is coherent with the beliefs of the teacher but may not be relevant in achieving any goals in the classroom. This is particularly true if the goals are extrinsic to the teacher. For example, aligned with a particular belief about collaborative learning, a teacher may implement portfolio assessment strategies in the class. According to Gearhart and Herman (1998), portfolios contain products of classroom instruction involving ‘an engaged community in a supportive learning process’ that is suitable for collaborative group learning. Research done by Webb (1993, 1995) suggests that an individual’s performance in the context of group activity may or may not represent his or her capability. In her finding, low ability students had higher scores on a group work than on individual work because efforts were assisted. Therefore, if the goal set for the class by the school is to do well for high stakes individual traditional assessments, students that did well in the portfolio assessment may or may not achieve their desired grades for the traditional assessments.

An overlapping of K and G but not B results in region 2. In this scenario, the teacher’s goals in the classroom are set by external influences such as the school, which may run contradictory to the teacher’s beliefs. Nevertheless, the teacher possesses the knowledge necessary to achieve the goals. For example, a teacher might strongly believe in collaborative learning in the classroom but under certain constraints in the school curriculum, a teacher might revert to didactic methods or rote learning to teach a particular lesson. A consideration of B and G together produces region 3. In this situation, the teacher may have multiple goals for the classroom but she has to weigh her goals according to her beliefs. For example, a teacher may have the dual goals of building an impressive portfolio for herself and having her students learn. However, when the goals conflict in any particular situation, the teacher will prioritize the goals based on her beliefs and this will impact the decision-making process in the classroom.

Regions 4, 5 and 6 denote classroom situations in which the teacher’s goals, beliefs and knowledge are mutually distinct without each having any influence on each other. Usually, these pertain to latent knowledge, goals and beliefs that were not relevant to the current teaching and learning situation of the teacher. However, these circular sets are not static but dynamic. Any changes to the external environment will trigger either a shift in or a resizing of any circular sets, to cause any dormant goals, beliefs and knowledge to intersect with one another. Region 8 lies outside of the KGB set. This region represents the external influences and social forces that can act on the teacher, thereby influencing the KGB diagram. The susceptibility to these changes is strongly subjected to the stability of the teacher’s KGB. Usually, a teacher with long teaching experiences has a far more stable KGB, as compared with a novice teacher. Thus, their susceptibility to changes is far less and their KGB diagram will remain relatively static as compared with a novice teacher whose KGB diagram is relatively more dynamic, with continual shifting and resizing of the circular sets.

The central region 7 represents the intersection of the teacher’s knowledge, beliefs and goals, the KGB region. This region denotes the teacher’s selection of...
knowledge, that based on goals, are prioritized by his or her beliefs. In other words, this region explains the type of teacher’s decisions in the classroom that are aligned with the teacher’s goals, beliefs and knowledge. In this view, good teaching with technology requires an alignment of the all three elements: K, G and B. In leveraging any technology effectively in teaching, the teacher must possess knowledge of the affordances of the technology and how to use the technology to achieve goals that are set for the classroom. Affordances refers to both the perceived and actual fundamental properties of technology that determine just how the technology could possibly be used (Norman 1990) and they are objectively measurable and independent of the individual’s ability to recognize them (Gibson 1977). Clearly in the KGB region, the goals and knowledge of the teacher are shaped and influenced by the teacher’s beliefs. Hence, the teacher’s beliefs, in this case, provide the affective motivation for teacher to utilize the technology.

The coherency diagram

Technology is treated as a knowledge system that is biased (Hickerman 1990) and possesses its own propensities, biases and inherent attributes (Bruce 1993; Bromley 1998). Some technology is more suitable for certain tasks than others. Thus, technology cannot be treated as a knowledge base unrelated from knowledge about teaching tasks and contexts – it is not only about what technology can do, but also, and perhaps more importantly, what technology can do for teachers (Koehler et al. 2007). Furthermore, for technology to become an integral component or tool for learning in the subject, teachers must also develop ‘an overarching conception of their subject matter with respect to technology and what it means to teach with technology pedagogical content knowledge (TPCK)’ (Niess 2005).

Angeli and Valanides (2009) argues that in leveraging technology in teaching, it is important to consider teacher’s beliefs, in addition to knowledge (content, technology and pedagogy). A disregard of teacher’s beliefs is considered as ‘naïve perceptions about the nature of integrating technology in teaching and learning.’ (Angeli & Valanides 2009, p. 157). Hence, we need to consider the teacher’s knowledge, goals and beliefs in relation to the affordances of the technology in order to study the harnessing of technology in teaching. To capture this relation, we introduce the coherency diagram (Fig 2) as a representation to describe the extent to which technology is leveraged in teaching in relation to the teacher’s KGB region.

In Fig 2, the size of the intersection region determines the extent of coherency between KGB region and the affordances of the technology. In other words, the greater the intersection, the more effectively the affordances of technology will be leveraged by the teacher in the classroom. The effective usage of any technology in the classroom must align with the knowledge, goals and beliefs of the teacher. As the teacher develops cognitive and affective competencies in the use of a technology, the KGB region will gradually be shifted more to the right, causing the intersection area to increase in size. On the contrary, the teacher may also develop negative views about the technology or misconceptions about the affordances of the technology that may affect the KGB region, causing it to shift to the left, thereby reducing the intersection area.

The coherency diagram is dynamic and exists in tandem with the teacher’s developmental trajectory in using technology in the classroom. If we map out the entire repertoire of intersection regions, one would realize that they lie in a continuum. Hence, the coherency diagram serves as an indicator of teacher’s developmental state in technology competency.

Four states in the continuum of coherency

Although the coherency diagram views the developmental stages in a continuum, it is useful to divide the continuum into four distinct states shown in Fig 3. These states encompass all possible classroom scenarios where technology is implemented. State 1 denotes pictorially that the affordances of the technol-
ogy are not leveraged by the teacher at all. This state forms one end of the continuum. As the intersection increases in state 2, technology is deployed to a limited extent in the classroom. Continuing along the continuum, state 3 denotes a situation where much coherency is depicted. In this case, technology is leveraged to a large extent. State 4 denotes the upper limit of the continuum. It is a state where all affordances of the technology are leveraged, and there is total coherency between the KGB region of the teacher and the affordances of the technology. This state forms the ideal state. The various states are not time dependent and a teacher could begin, progress, regress, or end at any state. They attempt not only to describe a teacher’s KGB region and its relation to the leveraging of the technology’s affordances at any one point, but also to serve as important indicators of her development progress from one state to another in using technology in the classroom. The transition from one state to another is qualitatively and quantitatively assessed in terms of the leveraging of affordances of the technology in the classroom.

**Research context**

Our focus in this study is the analysis of the teacher’s personal experiences in using the technology in the classroom. We adopt a case study approach in mapping out each teacher’s developmental trajectories using the Coherency diagram. This model provides a systematic framework for us to gather relevant data as to teachers’ knowledge, goals and beliefs about the GS technology at each developmental milestone, and to do comparative studies between different implementation paths taken by each teacher.

**Research and intervention context**

In our research project, we have collaborated with two teachers, namely, Lynn and May. These teachers were selected based on their different KGB characteristics so that a contrasting comparison can be done at the end of our study. Lynn is an experienced primary school teacher in the latter stages of her successful career in teaching. In contrast with other teachers in her school, Lynn (before our study) was a technology novice, using the computer mainly for recording grades, email communications and word processing. Despite this, she volunteered to participate in this project and was willing to move up the technology learning curve.

May is a young female teacher with about 5 years of teaching experience. She puts in effort in her classroom management, cares for her students and does not neglect the weaker students. She is under pressure to produce high-grade students as the school faces pressure to produce not just good students, but star students, so as to attract more parents to send their children to school. May is relatively more IT-savvy than Lynn.

In Singapore, the school year starts in January and ends in November. We started our study in July 2007 working with Lynn and May in their primary school in Singapore. Lynn and May teach different classes in grade 4. We started with 6 weeks of Paper Scribbles, which are activities using sticky paper notes, in the classrooms as an initiation phase. This is a means to
begin enculturating the teachers and the students into the practice of rapid collaborative brainstorming and critiquing, and to developing the relevant protocols and social etiquettes. Easy-to-use sticky notes are adopted to facilitate the students’ use in contributing ideas to an activity posed by the teacher and in commenting on each others’ postings.

Subsequently, the class switched to the use of the GS technology for 10 weeks. The students and teachers were provided training for two sessions of an hour each. They then used GS for science lessons for another 10 weeks. Each week, they had a 1 h GS science lesson in the computer laboratory. These GS lessons formed our primary core data for analysis. In our instructional design, we tried to incorporate the following ten principles, of which the latter five were adapted from Scardamalia (2002):

- distributed cognition – designing for thinking to be distributed across people, tools and artefacts,
- volunteerism – letting learners choose what piece of the activity they want to participate in,
- spontaneous participation – designing for quick, lightweight interaction driven by students themselves,
- multimodal expression – accommodating different modes of expression for different students,
- higher-order thinking – encouraging analysis, synthesis, evaluation, sorting, or categorizing,
- improvable ideas – providing a conducive environment where ideas can be critiqued and made better,
- idea diversity – exploring ideas and related/contrastng ideas, encouraging different ideas,
- epistemic agency – encouraging students to take responsibility for their own and one another’s learning,
- democratized knowledge – everybody participates and is a legitimate contributor to knowledge,
- symmetric knowledge advancement – expertise is distributed, and advanced via mutual exchanges.

In January 2008, we continue our involvement with the teachers; the students are now in grade 5. Every week for 10 weeks, two lesson periods (totalling an hour and 10 min) for the subjects of science and mathematics adopt GS lessons which are conducted in a computer lab. In these two classes of 40 students, each student has an individual Tablet-PC (TPC) with a GS client software installed. In total, we have co-designed, implemented and observed five mathematics lessons and eight science lessons as shown in Table 1.

### GS as a technology that supports rapid collaborative knowledge building

The motivation for our intervention in the school stems from the realization that there is an ever-increasing need to provide students with learning experiences that reflect the unique challenges and opportunities of the 21st century. One key class of skills relates to rapid collaborative knowledge building which include problem identification, brainstorming, prioritizing, concept mapping and action planning (DiGiano et al. 2006). By harnessing these techniques in the classroom, it is possible for students both to learn existing subject matter more deeply and also to become participants in 21st century knowledge building practices. These techniques can be enacted with a lightweight technology such as GS, which enables collaborative generation, collection and aggregation of ideas through a shared space based upon individual effort and social sharing of notes in graphical and textual form.

<table>
<thead>
<tr>
<th>Mathematics lessons</th>
<th>Mathematics topics</th>
<th>Science lessons</th>
<th>Science topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Equivalent fractions</td>
<td>Week 1</td>
<td>Genes</td>
</tr>
<tr>
<td>Week 2</td>
<td>Area of a triangle</td>
<td>Week 2</td>
<td>Parts of a flower</td>
</tr>
<tr>
<td>Week 3</td>
<td>Division of fractions</td>
<td>Week 3</td>
<td>Plant pollination</td>
</tr>
<tr>
<td>Week 4</td>
<td>Ratio of two quantities</td>
<td>Week 4</td>
<td>Seed dispersal</td>
</tr>
<tr>
<td>Week 5</td>
<td>Ratio of three quantities</td>
<td>Week 5</td>
<td>Plant reproduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Week 6</td>
<td>Stem cutting</td>
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<td></td>
<td></td>
<td>Week 7</td>
<td>Experiment planning</td>
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<tr>
<td></td>
<td></td>
<td>Week 8</td>
<td>Transfer of energy</td>
</tr>
</tbody>
</table>

Table 1. Topics that are taught in Lynn’s and May’s mathematics and science classes.
The GS user interface presents each user with a two-paneled window. The lower pane is the user’s personal work area, or ‘private board’, with a virtual pad of fresh ‘scribble sheets’ on which the user can draw or type (see Fig 4). The essential feature of the GS client is the combination of the private board where students can work individually and group boards or public boards where students can view others’ work, post their work and position it relative to others’ work, and take items back to the private board for further elaboration.

Figure 4 shows a lesson activity in class in which each student posts answers to the question ‘When does the heart beat faster/slower?’ in the private board, and then moves their answers to the public board for sharing. The students’ scribble notes showed a multiplicity of ideas they generated which enabled the teacher to initiate discussions on the interesting postings.

Table 2 depicts the basic features of GS that are suggestive of the affordances of GS for supporting student participation in designed collaborative activities. In collaborative classrooms, groups of learners and their teachers take on roles, contribute ideas, critique each other’s work, and together solve aspects of larger problems (Hake 1998).

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Table 2. GS features that support flexible collaborative work.

<table>
<thead>
<tr>
<th>Features</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representationally</td>
<td>GS can capture diagrams and drawings as well as text. Different sizes afford different kinds of activities.</td>
</tr>
<tr>
<td>Informal</td>
<td>GS uses relatively small size of virtual posting pads (scribbles sheet: 3 × 5 inch and label sheet: 3 × 3 inch) suited for quick sketches or notes instead of highly finished ideas.</td>
</tr>
<tr>
<td>Lightweight</td>
<td>The scribble sheets are for concise ideas instead of lengthy explanations.</td>
</tr>
<tr>
<td>Metainformatic</td>
<td>The scribble sheets can annotate other representations, including other posting sheets.</td>
</tr>
<tr>
<td>(Re)arrangable</td>
<td>The scribble sheets can be positioned and repositioned to convey meaning.</td>
</tr>
<tr>
<td>Unique</td>
<td>As a virtual artefact, each scribble sheet cannot be in more than one place at a time, suggesting turn-taking in editing or changing.</td>
</tr>
<tr>
<td>Shareable</td>
<td>The scribble sheet can be easily passed from one person to any group workspace. The same sheet can be retracted from the group workspace for refinement or elaboration.</td>
</tr>
<tr>
<td>Anonymous identity</td>
<td>GS has the feature of veiling the user’s identity. However, access to the identity of the author of each scribble sheet can be made available to the instructor.</td>
</tr>
</tbody>
</table>

Adapted from DiGiano et al. 2006.
GS, GroupScribbles.
Data collection

In our collection of data, two or more researchers observe each class and make detailed field observation notes. One video camera is set behind the classroom to record the classroom session, while two other video cameras are focused on two target groups of students. Screen capturing software Morae™ is installed on the TPCs to record the interaction of the students using GS. We approach our data analysis from different perspectives including uptake analysis (Looi et al. 2008), as well as analysis of surveys, interviews and performance tests (Ng et al. 2008). We have also employed semi-structured interviews as a method to gain access to the subjective understanding of the teacher. This includes an hour-long interview conducted at the end of the semester and weekly post-lesson conference sessions. In the post-lesson conference sessions, the teacher is prompted to reflect on the lesson and articulate her own analysis of the lesson. This proves to be a useful source of data for us, as it reveals many subtle beliefs that the teacher hold. In the end of the semester, the teacher is interviewed by two researchers with a list of prepared interview questions in a private location. The interview sessions are recorded by audio and video. In the work reported in this paper, our multifaceted data collection and analysis is situated in the frame of qualitative analysis and the case study formalisms of Stake (2000).

Analysis

This section discusses the use of the coherency diagrams in explaining May’s and Lynn’s various pivotal decisions to integrate technology into the curriculum. This is done by establishing their beliefs, goals and knowledge in the first instance and then employing them as lenses to explain and understand the various GS-related activities in the classroom.

Phases of technology implementation in the classroom

In our previous paper (Chen & Looi 2008), the different implementation phases of technology, namely the initiation phase, the implementation phase and the maturation phase are discussed in the context of Lynn’s developmental trajectory. Each phase denotes a general time-based developmental milestone for integrating technology in the classroom. However, the time required to progress from each phase to another varies from teacher to teacher. Every teacher has a different trajectory with different initiation, implementation and maturation phases, and these can be described with coherency diagrams.

The initiation phase denotes the teacher’s initial exposure to technology. The teacher must be convinced both affectively and cognitively to accept the technology in the classroom. In order for a teacher’s KGB region to be coherent with the affordances of technology, i.e. state 3 of Fig 3, the perceived affordances of the technology must align with the teacher’s KGB. More alignment will imply more intersection. Therefore, some practical recommendations at this phase include opportunities for the teacher to articulate her KGB during initial exposure to the technology and align the affordances of technology to her KGB. In the implementation phase, the teacher proceeds to use the technology in the classroom. If the perceived coherency in the initiation phase is enacted successfully in the real classroom, there will be an increase in her confidence in using the technology. Diagrammatically, this would be indicated by an increase in intersection between the KGB region and the affordances of the technology. If the converse occurs, it may signal a decrease in confidence and motivation to use the technology. This is indicated then, by a decrease in the intersection region, causing a regression. These units of developmental trajectories are shown in Fig 5. Therefore, affirming teacher’s confidence in the first few lessons is very important in building confidence and increasing motivation.

Lastly, the maturation phase denotes a phase where the teacher garners enough positive experience to use the technology despite technical glitches of the technology. This is the final phase if the teacher has persisted in using the technology. Another indicator is that the teacher may have found innovative ways in using the technology. Usually, this phase is characterized by state
3 or 4 of Fig 3 because it denotes certain technical competence and confidence in the teacher. Note that in the initiation and implementation phases, the teacher’s coherency diagram can occur at any point along the continuum of the coherency diagrams, i.e. states 1 to 4. However, there is a possibility that a teacher may not achieve the maturation phase at the end of the technology implementation period, especially if the teacher’s developmental trajectory is regressing along the coherency diagram continuum instead of progressing.

**Lynn’s developmental trajectory**

Lynn’s KGB is reported in our previous paper (Chen & Looi 2008). In this section, we illustrate Lynn’s developmental trajectory via the coherency diagrams, supporting our analysis by describing some empirical observations. This is summarized in Table 3.

**Initiation phase**

In the initiation phase, Lynn begins her developmental path at state 3. There is much alignment between her KGB and her perceptions of the affordance of the GS technology. First, she believes that as a teacher, patience with the students is very important to help students learn. She expresses this belief in her own words: ‘patience with the students is very important to make a child (student) learn. Raising your voice against them will make things worse.’ This belief is fundamental to other beliefs that she holds. She firmly believes that addressing the emotional needs of students is central to students’ learning, that in building a good rapport with the students, ‘the children need to know that teacher understands and cares about them,’ and that it is important to assure students that it is alright ‘not to know’. Therefore, she believes that students in her class should be comfortable enough to admit that they have made a mistake and that winning the hearts of the students is important in teaching and learning. Second, she believes that ‘not every student is the same’ and that they possess diverse abilities. She also resolves not to let any students in her class feel ‘inferior’. Students in her class have different strengths and because of these beliefs, she has put in place a collaborative culture that is suitable for the students to learn from each other. Lastly, she also believes in the importance of teaching ‘thinking skills in the classroom’. This belief motivates her to adopt pedagogies that teach cognitive skills such as posting good comments and designing questions for peer teaching.

Concerning beliefs about the use of technology in the classroom, Lynn expresses her views succinctly: ‘it is important to keep up with the times. Nobody forces me to use GS in my classroom. I believe that one must be positive in learning, especially in IT’. When asked further, Lynn reflects that this positive mindset is pivotal for her in overcoming obstacles in integrating GS in the classroom in the initiation stage and in exploiting the affordances of GS to the fullest. This intrinsic motivation to learn has led her to be open to changes and has resulted in good working relationship with the research staff.

Closely linked to her beliefs are her ‘overarching’ goals (Schoenfeld 1999) in integrating GS technology in her classroom. In the interview with Lynn, she expresses that her main goal is ‘to see her children (students) learn because this gives a lot of satisfaction’ to her. In a conversation with her Head of Department, he adds that Lynn took up GS technology because ‘it is an opportunity for her to build up her portfolio as a senior teacher as she is competing with another senior teacher’. We tend to infer that Lynn may hold two overarching goals, but her beliefs about teaching and learning may have helped her to prioritize the goal of ‘seeing her children (students) learn’ as a more important goal. Her beliefs have also provided a focus for Lynn to select knowledge appropriate for effective learning. Because of her long teaching career, Lynn possesses reasonably good content and pedagogical content knowledge of her teaching subjects – mathematics and science. This is confirmed in separate interviews with some of her students. One student notes that she is a ‘knowledgeable teacher who is correct most of the time’. They also comment that they ‘enjoyed her lessons and were able to understand what she was teaching’.

Because of her strong belief that every child is able to learn, Lynn has devised lessons that are relevant to the students and are able to leverage the affordances of GS to her advantage. Lynn perceived these affordances to be congruent with her student-centred beliefs and goals. The affordances of GS technology complement and enhance her knowledge of content, pedagogy, and her class. For example, the features of GS technology allow her to teach science lessons better in a collaborative setting. In addition, although she is a technology novice,
Table 3. Lynn’s developmental trajectory.

<table>
<thead>
<tr>
<th>Phases</th>
<th>Lynn’s knowledge (K)</th>
<th>Lynn’s beliefs (B)</th>
<th>Lynn’s goals (G)</th>
<th>Affordances of technology</th>
<th>Coherency diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td>Lynn’s knowledge about collaborative learning strategies and the different abilities among her students.</td>
<td>1 Lynn’s beliefs about the values of the different abilities in her students and the importance of peer learning. 2 She believes in the importance of being patient with her student including affirming and praising her students is important in learning.</td>
<td>Lynn’s goal is to create a good collaborative learning environment.</td>
<td>Lynn perceives that the shared spaces in GS provided a good platform to post, build and improve each other’s ideas to allow students to learn from one another.</td>
<td>Because there is much alignment with the Lynn’s KGB and the perceived technology, Lynn starts off with state 3.</td>
</tr>
<tr>
<td>Implementation</td>
<td>Lynn’s knowledge about different learning styles profiles in her students.</td>
<td>Lynn’s beliefs about the values of the different abilities in her students.</td>
<td>Lynn’s goal is to give students freedom to express their solutions in their desired form.</td>
<td>Lynn perceives that the multimodal affordances of GS are aligned with her KGB.</td>
<td>Lynn successfully utilizes the shared space in GS for collaborative learning.</td>
</tr>
<tr>
<td>Maturation</td>
<td>Lynns knowledge about collaborative learning strategies and the different abilities among her students.</td>
<td>1 Lynn’s beliefs about the values of the different abilities in her students and the importance of peer learning. 2 Also, she believes in the importance of being patient with her student including affirming and praising her students is important in learning.</td>
<td>Lynn’s goal is to create a good collaborative learning environment.</td>
<td>Lynn successfully implemented multimodal expressions in her GS class lessons. Lynn is able to handle technical glitches by devising ‘filler’ activities as well as minimizing glitches.</td>
<td>There are successes in implementing what Lynn perceived. Hence, there is increased confidence in using the GS technology. This would be in state 3.</td>
</tr>
<tr>
<td>phase</td>
<td>Lynns knowledge about different learning styles profiles in her students.</td>
<td>Lynn’s beliefs about the values of the different abilities in her students.</td>
<td>Lynn’s goal is to give students freedom to express their solutions in their desired form.</td>
<td>Lynns goal is to give students freedom to express their solutions in their desired form.</td>
<td>Lynn is able to handle technical glitches. Therefore, she is close to state 4.</td>
</tr>
</tbody>
</table>

White circle represents ‘KGB region’; Grey circle represents ‘Technology affordances’. GS, GroupScribbles; PD, professional development.
the user-friendliness features of GS gives her the confidence that she is able to learn it well later.

**Implementation phase**

In the implementation phase, Lynn implements what she perceived as coherent in the initiation phase in the classroom. In our case study, Lynn is able to leverage the multimodal and shared space affordances of the GS technology in her lessons.

**Multimodal expressions in GS.** In many of Lynn’s science lessons (weeks 1–5, 8; see Table 1), ‘live’ specimens are used for students to sense and observe. For example, she brings plant seeds for lesson 4 and flowers for lessons 2 and 3. By allowing students to observe and sense the specimens, she caters to the different learning styles (visual, tactile, kinesthetic and audio) of the students in her class. This stems from her belief that every student learns differently, as mentioned in section 4.1. This belief also causes her to leverage on the affordance of GS which allows students to express their answers on the pad in different forms such as drawing or typing, i.e. the ‘representationally neutral’ feature of GS as shown in Table 2. This has produced a rich variety of answers, as shown in Figs 6 and 7. In Fig 6, some students prefer to draw and colour while other students prefer to type. Some students prefer not to post anything but verbalize their answers during the lesson. Similarly in the mathematics lessons, different students articulate their answers in different modes as shown in Fig 7. Lynn’s belief in the diverse abilities and learning styles among her students motivates her to plan and implement lessons that cater to different learning styles of her students. In this way, the multimodal affordances of GS are leveraged upon.

**Shared space in GS as a platform for collaborative learning.** Lynn’s student-centred beliefs enable her to create a conducive environment that promotes collaborative learning. In her lessons, students are allowed to express their answers without fear of criticism. This is not only seen in verbal articulation but also in the written ideas on GS boards. Below is a transcript that happened in her science lesson on transfer of energy:

Lynn: What is the answer to the question? Anybody know?
Student 1: Eagle?
Lynn: Not really. However, that was a good attempt. Anybody else want to try?
(students in her class begin to see that the student who provides an inappropriate answer will not be reprimanded, more students raises their hands)
Student 2: Caterpillar.
Lynn: Very good answer. Whole class give student 2 a clap. (whole class gives a clap)
Lynn: Alright, everybody please write your answers on the GS groupboard.

Fig 6 Multimodal expressions in a Group-Scribbles science lesson.
Lynn encourages her students to give constructive comments so that their self-esteem might be boosted. She gives praise as much as possible and in her lessons, very few incidences of chiding are observed. Below is another transcript in her science lesson on seed dispersal.

Lynn: Tell me how the seeds can be dispersed? And give me some examples of it.
Student 1: By wind. Pollen grains.
Lynn: Very good! Other answers?
Student 2: By water.
Lynn: Any examples?
Student 2: ur. . . .
Lynn: Anybody can help student 2? I think student 2 has given a good answer but any examples? (Lynn did not scold student 2 for being unable to give the example)
Student 3: Coconut.
Lynn: Excellent!

In addition, her belief in the diverse abilities among her students causes her to value every view that her students articulated. She implements group collaborative learning because she believes it is a good avenue for students to build upon each others’ knowledge. She believes that collaboration maximizes learning, and thus is more willing to exploit the features of GS technology that support collaborative learning shown in Table 2, e.g. viewing other group boards, peer reviewing each other’s ideas, and posting ideas in real time as shown in Figs 6 and 7. These affordances are leveraged successfully in promoting collaborative learning.

Because of these reasons, we could observe substantial collaborative results, e.g. evidences of peer learning and critique, higher order thinking skills, richer content, etc., because of the collaborative culture that she has built in the class (Looi et al. 2008).

Maturation phase
After a period of implementation, she has reached close to state 4 in the maturation phase. In this phase, she has devised her own ways to cope with the limitations of the GS technology, such as devising suitable filler activities when the technology fails, complementing GS technology with Windows Journal™, and planning GS-related lessons under the constraints of the GS-technology (e.g. not loading large background pictures that will ‘hang’ the GS technology). Hence, as we trace the coherency diagrams, Lynn exhibits a positive upward growth from state 3 to state 4 in implementing technology successfully in the classroom. The transition from state 3 to state 4 is a smooth and relatively easy one for Lynn. Lynn enjoys the GS technology so much that she comments that she will ‘use GS in her classroom even when the researchers are not around’.

May’s developmental trajectory
Initiation phase
At the beginning of the intervention, May holds several primary beliefs about teaching and learning. First, she
believes that enabling the students to do well in the examinations is the primary task of the teacher. She expresses this belief in her own words, ‘I wanted my students to achieve academically. That is the most important’. Following closely to this primary belief, her lessons have orientations towards preparing students to perform on examinations. She expects herself to finish the syllabus on time adhering to a strict schedule called scheme of work (SOW). Second, she believes that her students are ‘generally weak and unable to articulate their answers well enough’ and generally believes that her students ‘need to be guided and are not used to independent learning’. This has caused her to employ didactic teaching strategies in her lessons, e.g. posing very close-ended questions and enacting IRE (Initiation-Response-Evaluation) episodes frequently in her lessons. Below shows a transcript in one of her science lesson on parts of a plant:

May: Which part of the plant will form the fruit? (Initiation-close ended question)
Student 1: Stigma (Response)
May: Stigma? That is not really the part (Evaluation-close ended)
Student 2: Style (Response)
Teacher: Style? Wrong. Sorry (Evaluation)

Third, she believes that strict classroom management is required to achieve optimal task behaviour in students. She cannot tolerate any excessive noise in her classroom and believes that discipline and orderliness is the way for students to learn effectively. She expects her students to follow her instructions in minute detail. Therefore, her goals include completing the SOW on time and expecting a quiet, disciplined and orderly class for every lesson.

Hence, May’s KGB region entails applying her knowledge of didactic strategies to ensure completion of the syllabus and preserving a disciplined class for every lesson, based on her beliefs that her students should be taught to be ‘exam-oriented’ and that they are generally unable to articulate their answers well enough. Therefore, in the initiation phase, May perceives many of the affordances of GS technology to be misaligned to her KGB region. The affordances of GS technology is primarily leveraged for collaborative learning which requires students to articulate their ideas and to work together in groups to solve open-ended questions posed by the teacher. In addition, collaborative learning demands more time, which will cause May not to complete her syllabus on time. Moreover, May faces difficulty in planning collaborative learning activities for GS-related lessons because of her limited knowledge concerning teaching methods. Lastly, Lynn once commented that May was ‘persuaded to join in the research collaboration in using GS technology’ without her consent being sought first. All these factors points to the incoherency between May’s KGB region and the affordances of GS technology, and this can be aptly indicated by state 1 as shown in Fig 1.

Implementation phase (part 1)
As May enacts the incoherencies perceived in the initiation phase, she is not able to leverage the technology effectively in the classroom. First, her fear of not being able to complete her lessons on time has materialized in some of her GS lessons as she could not complete her intended lesson objectives. This is partly because of her poor time management skills in a group collaborative lesson. From our classroom observations, we note that May constantly seeks to enforce strict discipline in her GS group collaboration lessons. This causes a lot of tension in the classroom as students tend to talk and articulate more during these lessons while May tries to maintain order in the classroom by giving numerous instructions and expects her students to comply. Here is an episode of May’s strict classroom management in a science lesson:

May: Have I finished my instruction?
Class: No.
May (repeated again in agitated tone): Have I finished my instruction?
Class: No.
May: Then why are you people starting to do your work already?
May (turned to student A): A, what did you do in X’s post?
May: What was my instruction? If you draw on your board, how are you going to drag it on your groupboard?
May (shouting): Everyone 2 fingers up! 2 FINGERS UP!

May wastes much lesson time in trying to enforce discipline in the GS lessons and she reckons that more time is needed for collaborative group work. She succinctly expresses this frustration: ‘GS is time consuming and draining. It has prevented me somehow from covering the syllabus.’ Second, technical glitches that have unexpectedly cropped up in her first few lessons have further reduced her confidence and motivation to use GS technology in her lessons. In fact, she has attributed the poor
implementation of the lesson plans to technical glitches in the technology rather than reflecting on the misalignment between her KGB region and affordances of the technology. Therefore, for the first half of the implementation phase, May does not exhibit any progress in leveraging technology effectively in her classroom. Basically, she seems to have stagnated at state 1.

Implementation phase (part 2)

Realizing May’s stagnation, we as researchers put in efforts to increase her confidence and motivation to use the GS technology. This was done in several ways. First, we attempted to encourage her after every post-lesson conferencing. Instead of reprimanding and pointing out her mistakes, we took pains to give recognition to whatever good practices May exhibited in the GS lessons. Second, we asked her to do some reflection of her own instead of us criticizing her lesson directly. Third, we conducted periodic professional development sessions (PD) for the teachers (Chen & Looi 2008). These serve as communication opportunities for May to learn good practices from Lynn as well as serving as a platform to share any problems they face in using GS, including their KGB. In fact, we have shown her videos of selected portions of May’s GS lesson to trigger her to reflect on the effectiveness of her teaching strategies. Surprisingly, May commented that she is not aware of some of the inappropriate teaching strategies she has employed, e.g. giving repetitive instructions. In her own words, ‘I think the videos showed in the PD session have caused me to reflect on some of the teaching practices seriously.’ Fourth, we have also deliberately given May more agency in planning collaborative lessons for GS. All these efforts have paid off when we detect some changes in May’s KGB.

First, May has shifted from IRE to probing students for deeper answers, and giving opportunities for her students to articulate their answers more. In one of the science lessons:

May: Can anyone tell me what is wrong with the answer.
Student A: Teacher, the answer is not correct.
May: I do not want to know what is right or wrong, I want to know the reason. Write your ideas on the Group-Scribbles scribble pad and post them on the groupboard.

In doing so, May has leveraged on the affordance of GS as a means for the students to share their ideas. Second, May became less teacher-centred in her lessons. Instead of giving the correct answers, she chose to use students’ prior knowledge written on the GS scribbles pad as a bridge to teach new concepts. For example, in another science lesson on plant reproduction, May wanted to teach the concept that seeds do not grow in plants:

May read the students’ answers from the GS scribbles sheets aloud and asked students to correct any incorrect ideas.

May: The flowers have seeds? Inside it?
Student A: The ‘seeds’ has not grown into a seed yet.
May: Then what is it that is inside the flower?
Student A: Ovule.

May has better leveraged on the affordance of GS technology, e.g. ‘shareable’ feature of GS shown in Table 2, as a result of a change in her teaching strategies. Lastly, May was more able to handle certain technical glitches that arose in using GS. In a science lesson where there was a glitch with the GS technology:

May: All not responding? Cancel and login again.
Some students talk when logging in again.
May: The more people talk, the more will the computer hang (jokes).
May then told students to use Window Journal to write their ideas and that she will restart the GS server.

In summary, the external support provided by researchers to May has affected some change in her KGB. Empirical evidence discussed previously has shown that she is able to leverage the GS technology better because of a change in her teaching strategies. This can be attributed to an increase in the intersection region between her KGB region and the affordances of the GS technology, caused by a shift in her KGB region as indicated by state 3.

Implementation phase (part 3)

One would expect May to progress towards state 4 as she leveraged more of the affordances of the GS technology, but apparently this was not so. In one of the recent interviews with her, she commented that ‘GS is more suited for higher ability students attributed to their ability to verbalize, dare to post and willing to learn from friends’. For the weaker students, she believes in ‘giving basic content first and use GS for enrichment due to lack of time and lack of prior knowledge. Weaker students need to be taught exam skills instead of thinking skills’. This is probably because of the recent examinations results.
that show better results for the high ability students but not for the weaker students. Because of the exam results, her KGB region may have shifted again and this results in a smaller intersection with the affordances of technology, signalling a regress into state 2.

**May’s developmental trajectory**

In Table 4, we attempt to tabulate May’s developmental trajectory according to the different phases described in the preceding sections. May’s KGB and her changes in KGB which directly impact the affordances of GS technology for each phase is systematically listed in the table. For each phase, the coherency diagram is used to represent the leveraging of GS technology by May and thus to map out her developmental trajectory.

**Comparison of Lynn and May’s developmental trajectory**

The developmental trajectories for Lynn and May are summarized pictorially in Table 4. In this table, we can see the usefulness of coherency diagrams in indicating the different developmental stages for both Lynn and May. In the next section, we will discuss several useful implications from the findings shown in Table 5.

**Discussion**

From Table 4, we can make some notable assertions concerning a teacher’s developmental trajectory in integrating technology. First, the transition between each state is unequal. From Lynn and May’s developmental trajectory, the transition from state 1 to any states is more difficult than transitions from other states. This is because shifting of the KGB region before they intersect at all with the affordances of the technology is a lot harder as the teacher has to change their beliefs radically to align with certain affordances of the technology. It is easier to modify existing beliefs to intersect more than replacing existing beliefs with new beliefs, i.e. transition from state 1. In May’s case, the researchers had to put in extra effort to increase her confidence and motivation during the PD sessions, by trying to change her KGB so she can transit to a higher state.

Second, it is not necessarily true that a teacher will always exhibit progress in integrating technology. In May’s case, she shows regression from state 3 to state 2. This regression is probably caused by external factors that are not within the teacher’s control. For example, the examination results have cast doubts upon the benefits of using GS technology in May’s class, forcing her to reevaluate her KGB again.

Third, it is possible to progress through multiple states in the implementation phase without achieving the maturation phase. For May’s case, she has not garnered enough positive experiences in integrating GS technology in her lessons to stabilize her KGB region. As shown in Table 4, her KGB region is susceptible to changes caused by external factors, i.e. exam results. In contrast, Lynn’s KGB region remains relatively stable, allowing her to transit smoothly to state 4 in the maturation phase.

Fourth, we conjecture a high possibility that Lynn will stay at that stage, even when the researcher support has been withdrawn. This is because the high coherency between Lynn’s KGB region and GS affordances at the maturation phase implies that Lynn has internalized the affordances of GS technology in her knowledge, goals and beliefs to a degree that, without any external intervention and support, Lynn should be able to continue to leverage GS technology in her classroom lessons. Moreover, the smooth linear development trajectory from state 3 to state 4 points to the high stability of Lynn’s KGB region as mentioned previously. The possibility of regression into lower states is highly unlikely. Additional evidence gathered has supported this conjecture. After the end of the research project, Lynn has been appointed as the Head of Level for Primary 3 and has been tasked to spearhead the implementation of GS technology throughout that whole level. This includes training and mentoring teachers to use GS in their lessons, co-designing suitable lesson plans, and sharing with teachers from other schools who are also interested in using GS. In contrast, May’s volatile and unstable nonlinear trajectory poses an unpredictable situation. The low coherency between her KGB region and the affordances of GS technology implies that May needs stable external support (from school or researcher) before she can progress from state 2 to state 4. This is supported by the fact that May is not involved in leading any school-based GS-related projects since the end of the research project.

Lastly, researchers have provided appropriate technical, pedagogical and psychological support in the course of the project, in order to accelerate upward growth of the teachers’ integration of technology in the
Table 4. May’s developmental trajectory.

<table>
<thead>
<tr>
<th>Phases</th>
<th>May’s knowledge (K)</th>
<th>May’s beliefs (B)</th>
<th>May’s goals (G)</th>
<th>Affordances of technology</th>
<th>Coherency diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation phase</td>
<td>1 May possesses knowledge of didactic teaching strategies, i.e., IRE episodes in the lessons. However, she possesses limited knowledge of collaborative learning teaching strategies.</td>
<td>1 May believes that enabling students to do well in the examination is the primary task of the teacher. 2 May believes that her students are generally weak and are unable to articulate well. 3 May believes in strict classroom management. 4 May believes in teacher-centred approach in teaching.</td>
<td>1 May’s goal is to complete the scheme of work (syllabus) on time. 2 May’s goal is to create a quiet, disciplined and orderly class every lesson.</td>
<td>There is a misalignment between the affordances of GS technology and May’s KGB region.</td>
<td>Misalignment and no coherency as shown in state 1.</td>
</tr>
<tr>
<td>Implementation phase (part 1)</td>
<td>1 May possesses knowledge of didactic teaching strategies, i.e., IRE episodes in the lessons. However, she possesses limited knowledge of collaborative learning teaching strategies.</td>
<td>1 May’s goal is to complete the scheme of work on time. 2 May’s goal is to create a quiet, disciplined and orderly class every lesson.</td>
<td>1 May’s goal is to complete the scheme of work on time. 2 May’s goal is to create a quiet, disciplined and orderly class every lesson.</td>
<td>The perceived incoherencies during the initiation phase are enacted in this phase. The affordances of GS technology are not leveraged effectively. Attributed poor implementation to technical glitches.</td>
<td>The perceived in the initiation phase is enacted in the classroom. No growth.</td>
</tr>
<tr>
<td>Implementation phase (part 2)</td>
<td>1 May learns some collaborative learning strategies via PD sessions and self reflections. 2 May is able to handle technical glitches.</td>
<td>1 May becomes less teacher-centred. 2 May is giving more opportunities for students to speak and articulate their ideas.</td>
<td>1 May’s goal to use student’s prior knowledge as a bridge to teach new concepts.</td>
<td>1 May leverages on GS technology as a platform to draw students’ prior knowledge. 2 May utilizes multimodal affordance to allow students express their ideas.</td>
<td>Due to a change of teaching strategies, there are some leverages of GS technology in state 3.</td>
</tr>
<tr>
<td>Implementation phase (part 3)</td>
<td>1 May has knowledge of interim examination results of her students. 2 May realizes that she faces time constraints in completing the curriculum.</td>
<td>May believes that GS technology is better suited for high ability students. Weaker students should be taught exam skills instead of thinking skills.</td>
<td>May’s goal is to allow more of her weaker students to score better in tests and exams.</td>
<td>May perceives that GS technology may not be suitable for weaker students.</td>
<td>There is a regression.</td>
</tr>
</tbody>
</table>

classroom within a limited time frame. In a normal school context, the equivalent support from school leaders, senior teachers, vendors and consultants can also be given to trigger such development. We hope that the Coherency diagram is a generalizable mode that can be used to analyse a teachers’ developmental trajectory in any school context. From our studies, the Coherency diagram points to the amount and type of support required by the teacher; for example at states 1 and 2, the teacher requires much more support to grow professionally and use technology effectively in the classroom.

**Conclusion**

In this paper, we attempt to use the notion of Coherency diagrams to analyse teachers’ developmental trajectories in integrating GS technology. Our results show that the coherency between a teacher’s beliefs, goals and knowledge and the affordances of the technology is the main key in leveraging the technology successfully. The transition between each state of the coherency diagrams is nonlinear, implying the importance of ensuring high coherency right at the initiation stage. Support for the teacher, either from other teachers and/or researchers, remains an important factor in developing the teacher’s competency to leverage the technology successfully. The stability of the KGB region further ensures smooth progressing of the teacher’s effective integration of technology in the classroom.

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