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A 2×3 Model of Student-Directed Formative Assessment in Collaborative Knowledge Creation

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Abstract: We develop a 2×3 model to guide formative assessment of Bereiter and Scardamalia's knowledge creation. The notion of students as both knowledge creators and assessors of their own learning gives rise to theoretical and methodological issues; we explore these by putting them under a broad array of powerful theoretical perspectives, which involve the contemporary research in CSCL, self-regulated learning (SRL), metacognition, and motivation. The central idea fusing these various perspectives is the notion of human agency in Bandura's social cognitive theory.

Keywords: CSCL, collaborative knowledge creation, formative assessment, human agency, self-regulation, metacognition, motivation

Introduction

According to the principle of *epistemic agency* (Scardamalia. 2002), students participating in collaborative knowledge creation are presumably able to set forth their own goals and ideas, and to calibrate gaps between their personal understanding and other group members' understanding. This principle suggests that students, as active knowledge creators, are agents of their own learning, and of the progress of collaborative inquiry. In accordance with the view of Assessment *as* Learning (Earl, 2003; Guskey & Marzano, 2003; Carless, Joughin, Liu, & associates, 2006), epistemic agency essentially entails a dual role of students – not only as *learners*, but also as *assessors* of their own learning and collaborative inquiry in CSCL settings.

This dual role of students requires researchers to integrate assessments theoretically and methodologically into research on the key aspects of CSCL in a systematic and comprehensive way. Therefore, in this paper we propose a model of student-directed formative assessments (SDFA) in CSCL. This model characterizes SDFA in collaborative knowledge creation processes by revealing (1) how the notion of human agency is manifested through the mechanism of SDFA, and (2) whether and how this kind of assessments empowers students as agents of their lifelong learning under various circumstances.

In general, this is a 2×3 model shown on Table 1 suggesting that SDFA be conducted at two levels (individual and group) and along three dimensions (learning/knowledge creation, collaboration, and regulation). The two-level feature of the model is in accord with the view that collaborative knowledge creation is a self-organizing system (Bereiter, 2002), in which emergent group-level phenomena are the results of dynamic interactions among numerous individual-level elements (Carver & Scheier, 2002). It also extends our earlier work (van Aalst & Chan, 2007) in which we aimed to assess both individual and

collective aspects of knowledge creation. Each cell of the table defines assessment at a given level and in each dimension. The next two sections elaborate the theoretical underpinnings of the model and the implications for assessment.

Table 1. Description of the 2×3 Model of Student-Directed Formative Assessments

	Learning/knowledge Creation	*Collaboration*	*Regulation*
Individual-level	Personal cognition	Personal contributions to collaborative inquiry	Self-regulation of personal cognitive and motivational processes
Group-level	Collective knowledge creation/group cognition	Collective cognitive responsibility	Shared-regulation of collaborative inquiry processes

1. Theoretical Underpinnings of the Model

We think that the conceptual framework of this 2×3 model can be used to address the following crucial questions. What is the role of students in SDFA? What is the theoretical foundation on which students are put at the heart of assessments in CSCL? Why do we intend to view students' regulation of learning as the content of assessment? And what are the relationships among those three dimensions? Our model is intended to obtain a balance between individual and group-level assessments, and between cognitive processes, social practices, and regulatory processes of learning and collaboration.

1.1. The Role of Students in Formative Assessments in Knowledge Building

Three approaches to assessment in classrooms have been identified and studied: Assessment *of* Learning (AoL), Assessment *for* Learning (AfL) (Black & Wiliam, 1998), and Assessment *as* Learning (AaL; Earl, 2003; Guskey & Marzano, 2003; Carless, et al., 2006). AoL, also known as summative assessment, has been predominant in education (Guskey & Marzano, 2003). The purpose of this kind of assessment is to help teachers make judgments of individual students' achievement at the end of teaching. When an assessment is designed for improving ongoing learning, its function is *formative*. A dominating perspective is that AfL (i.e., formative assessment) is to help teachers identify students' strengths and weaknesses, so that teachers can adjust adaptively instructional strategies aiming at improving the effectiveness of instruction on their students' learning. It can be seen that the supportive function of formative assessment for learning is realized/mediated by teacher's work in improving their teaching, although many studies stress that formative assessment should be embedded in curriculum, teaching, and learning (Shavelson, Young, Ayala, Brandon, & Furtak, 2008). As in summative assessment, teachers are the central persona in designing and administrating AfL (Guskey & Marzano, 2003), so AfL is still teacher-directed. The perspective of AaL invites students to be actively engaged in, and critical assessors of their own learning in individual learning settings. In light of this view of formative assessment, assessment is the integral part of learning, and assessment tasks are learning tasks (Carless, et al., 2006). Thus, when students are engaged in learning activities, they should be motivated and able to personally monitor, assess and evaluate the progress of their own learning, make sense of information generated from all sources of assessments (e.g., self or peer-assessment), relate it to prior

and current knowledge, and take actions on their cognitive and motivational processes accordingly (Earl, 2003). In this sense, AaL essentially is more or less student-directed and self-regulating involving motivation and metacognition.

Student-directed formative assessments inherently entail students as agents of their own learning to involve two kinds of activities in assessments (Carless, et al., 2006). First, students need to access the information about their own knowledge, understanding, attitude or skills. Second, they need to be able to make metacognitive judgments of the quality and progress of their work, and take actions improve it. In other words, students presumably play two types of role simultaneously in SDFA - learners, and assessors/evaluators. This dual-role gives rise to high expectations as to the learner characteristics students should posses. There is little research on this central assumption assuring formative assessments can be effectively directed and regulated by students themselves. Comparatively, the complexity and specialty of student-directed formative assessment arises partly from this dual-role character of students, as well as its two-level structure resulting from the social nature of collaborative learning – individual vs. group .

It is realized that there is a need to give the agency to students in order for them to be able to assess their own and the community' knowledge advance, and the major long-term benefit of our model is to show how students can be agents of their own lifelong learning. Thus, we will introduce the notion of human agency under Bandura's social cognitive theory, a key to theorizing the unique dual-role of students in assessment as learning.

1.2. Human Agency – Fundamental Assumption of Student-Directed Formative Assessments

The notion of agency assumes that individuals possess self-beliefs that enable them to control their thoughts, feelings, and actions (Bandura, 2001). Furthermore, human agency refers to an emergent capability of individual humans to make choices (i.e. setting forth ideas and goals) and to act on these choices constituted primarily through interaction between brain activities and sociocultural contexts (Bandura, 2001; Martin, 2004). Agency is both *determined by* and *determining* the environment, and is philosophically connected to Piagetian constructivism, Vygotskian socioculturalism, and determinism (Martin, 2004). Agency has four main features *intentionality*, *forethought*, *self-reactiveness*, and *self-reflectiveness* (Bandura, 2001, 2006).

Intentionality represents the power to originate actions for a given purpose. "To be an agent is to intentionally make things happen by one's actions" (Bandura, 2001, p. 2). An intention refers to not only an expectation or prediction of future actions but also a proactive commitment to realize the expected actions. Forethought suggests that human behavior is motivated and directed by anticipated goals and outcomes, as well as planning (Bandura, 2001). An agent is supposed to be able to take appropriate actions, and to self-regulate motivation, affect, and action through goal setting. In this sense, presumably SDFA is goal-directed. Thus, it is necessary to figure out whether and how students' formative assessments in a knowledge-creation community are guided by either individual or shared learning goals to design productive student-directed formative assessments. Self-reactiveness suggests an agent "has to be not only a planner and forethinker, but a motivator and self-regulator as well" (Bandura, 2001, p. 8). Agents are assumed to have not only the deliberative ability to make choices and action plans, but also the ability to act on appropriate courses of action and to motivate and regulate their execution. Self-directedness links thought to action through self-regulatory processes in which individuals self-monitor their thoughts and actions, as well as environmental conditions under which thoughts and actions occur. Finally, self-reflectiveness entails agents possess the metacognitive capability to reflect upon oneself, because "People are not only agents of action but self-examiners of their functioning" (Bandura, 2001, p. 10). Self-reflectiveness

represents agents' metacognitive ability to subjectively judge their online state of learning against the goals as standards they intentionally set with shaping from external feedback from peers or teachers.

Together, these four core features of agency enable people to take responsibility for their self-development, adaptation, and self-renewal (Bandura, 2001). The first two are essentially associated with the role of motivation in human behavior; the last two attach the importance to people's metacognitive knowledge about and capability to self-monitor and control cognition, motivation and behavior. This means that in SDFA students should not simply wait for teacher to tell them the outputs of assessments, but rather be able to motivationally and metacognitively monitor, assess and evaluate what they are learning and what they are collectively constructing, meaningfully interpret assessment data, and then make accurate judgments and take appropriate actions to control the progress of their own learning and collaborative knowledge-construction discourse.

Accordingly, SDFA is a self-regulatory processes in which students in a CSCL community need to motivationally (intentionally) and metcognitively self-and co-regulate the whole process of assessment that is directed traditionally by teacher. This is why we intend to introduce the regulation dimension as not only a key content of, but also the driving force of SDFA in this innovative model.

1.3. Metacognition and Motivation – Two Propelling Engines for Student-Directed Formative Assessments

There are two at least constraints to the effectiveness of SDFA. First, it relies on the degree and extent to which quality data about learning are accessible to students. Second, it depends on whether and how students can interpret, make sense of, as well as meaningfully relate the data to their own learning and collaborative inquiry. In other words, the formative function of assessments not only depends on how much meaningful information students are able to identify and discover from such data, but also whether or not they are motivated and able to make use of the information to advance their individual learning and collaborative inquiry. The validity of a formative assessment for learning depends on how far students' interpretation and use of the assessment actually leads to further learning (Hargreaves, 2007). The first constraint can be lifted at least by designing practical assessments that can precisely trace and capture individual cognitive operations and collaborative inquiry activities recorded as logfile data in a computer system like Knowledge Forum®. The removal of the second constraint depends on the degree to which students are given to the agency to monitor, assess/evaluate, and control their own learning and collaborative inquiry, and how well metacognition and motivation can be fostered by self-directed formative assessments. In our model, agency is both prerequisite to effective student-directed formative assessment and its anticipated output. Thus, it is imperative to take motivation and metacognition into account for establishing the conceptual framework of our model, because this is an intrinsic demand of student-directed formative assessments.

First, metacognition refers to the knowledge and beliefs about one's cognitive processes, as well as capabilities of planning, monitoring, and controlling cognitive processes (Koriat, 2007; Veenman, Van Hout-Wolters & Afflerbach, 2006). There are two types of operations: *metacognitive monitoring* and *metacognitive control* (Winne, 1996, 2001). According to Winne, the former refers to learners' subjective judgments of their degree or nature of learning before, during, and after study. The latter is deciding how to act based on the products of metacognitive monitoring, and this control determines the progress of learning. Our work will expand the definition of metacognition in collaborative learning settings in which students not only need monitor and control individual cognitive processes, but also the advancement of group cognition (Stahl, 2006).

Second, motivation that is defined as "the process whereby goal-directed activity is instigated and sustained." (Schunk, Printich, Meece, 2008, p. 4) is viewed as dynamic and context-specific rather than static and trait-like (Jäevelä & Volet, 2004; Jäevelä, Järvenoja &

Veermans, 2008). It is dynamically initiated, shaped, and sustained through an active and ongoing co-regulatory process (McCaslin & Hickey, 2001). The view of social and dynamic nature of motivation theoretically supports our commitment to investigating the role of motivation in SDFA.

Motivation as a multi-faceted construct embraces a number of sub-concepts such as self-efficacy, goal orientation, and task value, (Schunk, et al, 2008). Very little research can be found from the literature on the roles these motivational variables played in student-directed formative assessments in CSCL settings. A hypothesis in this regard is that the impact of motivation on the effectiveness of assessment is realized by students' selective attentions to various available assessment data. In other words, the formative function of assessments presumably varies with the variation of learner characteristics. For example, students who have higher tendency (high social goal orientation) to help others in collaboration is assumed to be higher sensitive to the assessments related to their positions relative to others in a social network than those who have lower social goal orientation. One of the objectives of our study is to understand how formative assessments mediate the improvements of individual learning and collaborative inquiry. However, it is hypothesized that the mediatory role of formative assessments in learning is moderated by student motivation. Goal orientation reflects a standard by which learners make judge the success or failure of their learning outcomes (Schunk et al., 2008); accordingly it impacts the effectiveness of formative assessment by the standards against which students use to assess their individual and collaborative learning. The complexity of the model lies in the idea that the student motivation in our model is no longer reviewed as a static, trait-like construct, and is continuously re-shaped through social interactions occurring in collaborative inquiries.

2. Design Considerations

Table 1 shows the two-level structure of this model. Each cell in the table represents the content of assessment at a given level and in a given dimension, which will be defined in the subsequent section.

At the individual level, *personal cognition* in the dimension of learning/knowledge-construction refers to the aspect of individual conceptual understanding of what students are learning in a knowledge-creation community, corresponding to the conventional assessments of individual learning. The second dimension at this level is *collaboration*. This model invites students not only to assess their own personal cognitive processes, but also to intentionally assess how they behave in collaboration by exchanging ideas with others, asking questions, prosing new ideas, commenting/questioning peers' ideas and theories, and so on. This is an individual-level assessment that points to individual's own performances rather than others' in collaborative learning activities, and are mainly measured as the frequencies of notes read, built on, and referenced by each individual student in a Knowledge Forum database. Notably, *regulation* is treated both as the target of and as a critical condition underlying student-directed formative assessments. Simply, the individual-level regulation refers to self-and/or peer-assessments of individual self-regulation of their own cognitive and motivational processes. Regulation of learning involves goal setting, metacognitive monitor and control of cognitive and motivational processes as learning unfolds (Winne, 2001). SDFA as self-regulatory processes naturally concerns the above metacognitive processes. For example, students need to ask themselves such questions in self-assessments as whether and how well they have set their learning goals, how accurately they monitored the degree of their conceptual understanding by calibrating the gap between their subjective judgment of learning and their actual learning achievement, and whether they were over-confident or under-confident in their own learning achievement. We have not found any study in the literature on CSCL examining how students' self-assessments of the regulation of their own cognitive processes impact learning.

At the group-level, the learning/knowledge creation dimension in the model refers to the advancement of collective knowledge or group cognition (Stahl, 2006) that is viewed as the

product of knowledge creation (Bereiter, 2002; Scardamalia & Bereiter, 2006). As a group-level emergent phenomenon, collective knowledge or group cognition cannot emerge only from the discrete individual cognitive processes, but rather is generated through social interactions in collaborative inquiry. *Collective cognitive responsibility* (Scardamalia, 2002), a defining feature of knowledge creation theory, plays a central role in initiating and maintaining progressive collaborative inquiry, and eventually resulting in collective knowledge. It requires students in collaboration to understand the top-level (group-level) learning goals and shared responsibility for advancing community knowledge (Zhang, Scardamalia, Reeve & Messina, 2009).

Collective cognitive responsibility has operationally been broken down into three dimensions (Zhang, et al., 2009): *awareness of contributions*, c*omplementary contributions*, and *distributed engagement.* Awareness of contribution is defined as students' awareness (knowing) of their knowledge building community (e.g., emergent ideas, and the connections among them), and is merely measured in Zhang, et al's study as the percentage of notes and percentage of inquiry threads each student read. Besides that quantitative approach, in our model, awareness of contribution will be extensively examined by an array of methods such as e-portfolio (van Aalst & Chan, 2007), online task-specific questionnaire (Jäevelä, et al., 2008).

Complimentary contribution refers to that students in a knowledge creation community are committed to building on one another's ideas, connecting and rising the diverse ideas to emergent knowledge at the high-level. Zhang, et al, (2009) measured it as percentage of notes that are linked by various cognitive operations such as building on, rising above, or referencing other authors. These measures, however, merely reveal a structural link among notes as units containing individual's ideas and theories in online discussions. In formative assessment, students need not only to access to the information regarding how the notes (their own and others') are structurally linked to one another, but, more importantly, to be aware how the notes embracing ideas are semantically linked together. For example, the Knowledge Space Visualizer (KSV) is a tool that visualizes both structural and semantic relations among notes (Teplovs & Scardamalia, 2007) using social network analysis in combination with latent semantic analysis (LSA). Specifically, Figure 1 displays the structural network of notes of a knowledge creation community. The semantic links among the same notes shown on Figure 1 are displayed on Figure 2. It can be seen that there are some notes that are linked to one another semantically but not structurally. Meanwhile, the note at the center in the structural network is not necessarily at the center in the semantic network.

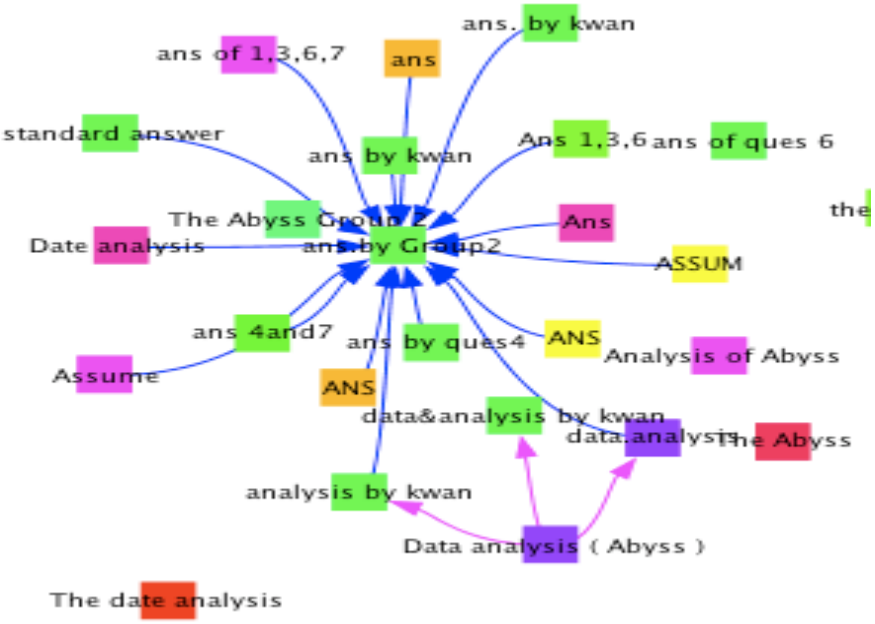

Figure 1. Layout of A Structural Network of Notes In Knowledge Space Visualizer (KSV)

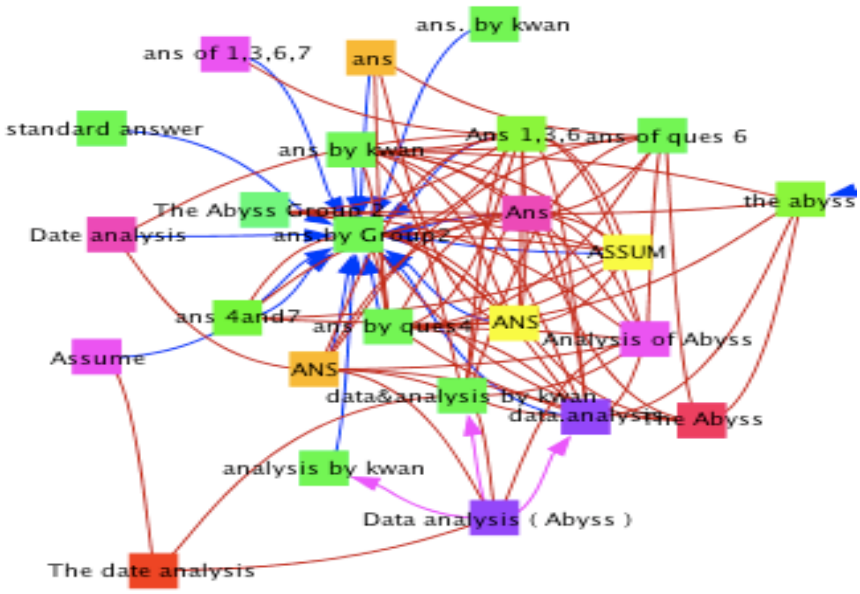

Figure 2. Layout of Both The Structural Network of Notes And Semantic Network of Notes In Knowledge Space Visualizer (KSV)

As the third component of collective cognitive responsibility, distributed engagement requires that all students "engage in top-level planning, decision making, and community coordination," (Zhang, et al., 2009). So, all students need to not only engage in the shared cognitive activities, but also in regulating them by defining inquiry goals, selecting tactics and strategies, etc. Similarly, the group-level regulation dimension in our 2×3 model primarily involves students' assessment of their own distributed engagement, namely, assessment of co-regulation (Volet, Summers, & Thurman, 2009).

In our model, student-directed formative assessments in CSCL rely on three sources of data: *system-generated, student-generated*, and *teacher-generated*. Applets in Knowledge Forum exemplify the potential use of system-generated data by visualizing individual participation of collaborative inquiry. Visualization of participation is conducive to successful CSCL (Janssen, Erkens, Kanselaar, & Jaspers, 2007). Student-generated assessment data can be resulted from either self-assessments such as student-directed e-portfolio (van Aalst & Chan, 2007), self-report questionnaires, online self-test quizzes, or peer-assessments embedded in the notes commenting and evaluating others' ideas. Teacher's feedback, comments, and grading are teacher-generated data. A challenge is how various assessments from these sources are systematically combined within a unifying model in a way that is conducive to students to exercise their agencies, as well as improving self-regulatory capabilities as agency in their lifelong learning.

Conclusion

The underlying feature of this 2×3 model student-directed formative assessment lies in the recognition of the dual-role of students as agents in the assessment, which entails to intrinsically integrate self-and co-regulation into the course of individual learning and collaborative knowledge creation. As a result, students' regulatory processes not only function as underlying factor in assessment, but also are viewed as the integral content of assessment in the present model. The model theoretically and methodologically combines research in self-regulated learning, metacognition and motivation with formative assessments in CSCL. Contemporary cognitive, learning, and educational sciences are proceeding along two lines (Bandura, 2001). One line heavily focuses on the basic mechanisms of the human mind (e.g., SRL theories). The second line of theorizing centers on socially situated factors in human

development (e.g., knowledge creation). A comprehensive theory that integrates these two lines within a unified causal structure is still lacking (Bandura, 2001). Our work will contribute to the ongoing fusion of these two lines of research in the field of learning sciences.

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