Representations of Progress in a Learning Community Curriculum for Grade 12 Biology

Alisa Acosta, University of Toronto, alisa.acosta@utoronto.ca
James D. Slotta, Boston College, slotta@bc.edu

Abstract: This paper reports on the design and implementation of several student- and teacher-facing learning analytics representations within a blended learning community curriculum for Grade 12 Biology. Using a custom designed technology environment called *CKBiology*, these representations captured the real-time progress of the learning community at three levels of granularity: Individual students, small groups, and whole class. Our results focus on the perspectives of students and teachers, triangulating data from a student questionnaire, teacher interview, and CKBiology log files to identify how different representations of progress contributed to awareness, motivation, and the overall practices of the learning community. Grounded in the theoretical model of *Knowledge Community and Inquiry*, this work seeks to strengthen connections between learning analytics research and the learning sciences.

Introduction

Learning communities are characterized by a culture of learning wherein all participants are involved in a collective effort of understanding (Bielaczyc & Collins, 1999). As Kling and Courtright (2003) observe, "developing a group into a community is a major accomplishment that requires special processes and practices, and the experience is often both frustrating and satisfying for the participants" (p. 221). One prominent challenge in adopting learning community approaches is that of assessment (van Aalst & Chan, 2007). In contrast to traditional forms of instruction, wherein the teacher has sole authority over the assessment of students' work, learning communities provide students with a greater level of agency, allowing them to "develop ways to assess their own progress and work with others to assess the community's progress" (Bielaczyc & Collins, 1999, p. 272). Thus, in a learning community curriculum the activity designs must clearly articulate the learning processes, making them visible and accessible for assessment. Furthermore, because learning communities focus on both individual and collective aspects of knowledge production, assessment in these contexts must serve the dual function of both measuring and scaffolding learning, producing a "feedforward effect" that serves to catalyze the development of new knowledge (Scardamalia & Bereiter, 2006; van Aalst & Chan, 2007).

This paper reports on the design and implementation of several student- and teacher-facing learning analytic representations within a learning community curriculum for Grade 12 Biology. Using a custom designed technology environment called *CKBiology*, these representations captured real-time progress of the community at three levels of granularity: Individual students, small groups, and whole class. Grounded in the theoretical model of Knowledge Community and Inquiry (KCI; Slotta, 2014), this work responds to two of the challenge areas identified by Ferguson (2012) concerning learning analytics: 1) Building strong connections to the learning sciences, and 2) focusing on the perspectives of learners. In this study, we triangulate data from a student questionnaire, teacher interview, and CKBiology log files to respond to the following research questions:

1. What forms of representation allow students and the teacher to perceive progress (or gaps in progress) within a learning community?
2. To what extent do these representations motivate students to contribute to the learning community?
3. How are these representations used by the teacher in orchestrating the learning community?

The goals of this research are closely aligned with those identified by Buckingham Shum and Crick (2016) concerning learning analytics for formative assessment of 21st century competencies: "to forge new links from the body of educational/learning sciences research—which typically clarifies the nature of the phenomena under question using representations and language for researchers—to documenting how data, algorithms, code, and user interfaces come together through coherent design in order to automate such analyses, providing actionable insight for the educators, students, and other stakeholders who constitute the learning system" (p. 8).

Literature review

Knowledge Community and Inquiry (KCI)

For many years, theories on collaborative learning tended to focus on how participating in a group would affect an individual's performance (Stahl, 2015). However, in the late 1980s two programs of research emerged that situated groups of learners within a broader community level: Fostering Communities of Learners (FCL; Brown & Campione, 1994) and Knowledge Building (KB; Scardamalia & Bereiter, 2006). FCL and KB differ with respect to the objectives of the community, the centrality of student-generated ideas, and the level of emphasis placed on prescribed learning goals. However, both of these research programs advanced the notion that the activities occurring in school classrooms should mirror those of authentic research communities, incorporating aspects of collective epistemology and community-level knowledge advancement (Brown, 1994; Scardamalia & Bereiter, 2006). Building upon this body of research, author Jim Slotta developed a pedagogical model called *Knowledge Community and Inquiry* (KCI) as a means of integrating the perspectives of KB and FCL and making learning community approaches more accessible to researchers and practitioners. As in FCL and KB, students in a KCI classroom work together as a community, building upon each other's knowledge and nurturing a collective epistemology. However, in a departure from KB, an important aspect of KCI is the design of curricular *scripts* (Fischer, Kollar, Stegmann, & Wecker, 2013) which specify the activity sequences, materials, student groupings, and technology elements that serve to guide the inquiry toward particular learning goals. KCI curriculum designs are guided by five major design principles, each accompanied by a set of epistemological commitments, pedagogical affordances, and technology elements (Slotta, 2014).

Student- and teacher-facing learning analytics

Learning analytics (LA) entails the application of data science techniques, such as probability modeling and data visualization, to educational data in order to generate actionable knowledge to support teaching and learning (Duval, 2011; Siemens, 2012). Because of its origins in online courseware environments, which typically embraced knowledge-transmission modes of pedagogy, a large proportion of LA research maintains a focus on assessment at the level of individual learners, emphasizing individual achievement and accountability (Chen & Zhang, 2016; Schwartz & Arena, 2013). A systematic literature review performed by Schwendimann et al. (2016) revealed that the primary audience for most LA dashboards was course instructors (71%) and that the predominant context was university settings. Furthermore, only 5% of papers reviewed included an explicit theoretical basis for its LA designs (Schwendimann et al., 2016). In a subsequent literature review focusing on student-facing LA dashboards, Jivet et al (2017) revealed that only 26 out of 95 dashboards had a) been empirically evaluated, and b) had any theoretical grounding in the learning sciences. Of those that did, 18 of 26 were rooted in cognitivist theory and promoted competitive, rather than collaborative, learning behaviors (Jivet et al., 2017). While some researchers have begun to apply LA to more collaborative learning scenarios (e.g. Bachour, Kaplan, & Dillenbourg, 2010; Blikstein & Worsley, 2016; Ferguson & Buckingham Shum, 2012; Shaffer et al., 2009), many of these studies report on tools and approaches that have been customized for the researchers, often entailing specialized equipment, complex visual outputs, or data formatting requirements that impede adoption by students and teachers (Vatrapu, Teplovs, Fujita, & Bull, 2011).

This paper responds to a central challenge in learning analytics research of interpreting and responding to analytic information within the flow of curricular activities. Wise and Vytasek (2017) define a *learning analytics implementation design* as "the purposeful framing of activity surrounding how analytic tools, data, and reports are taken up and used as part of an educational endeavor" (p. 151). LA implementation designs address questions such as who should have access to particular kinds of LA, why these LA are being consulted, and how the LA can be fed back into the educational processes taking place (Wise & Vytasek, 2017). Such questions can be incorporated into a curricular *script*, which specifies how and when to constrain particular interactions, the sequence in which activities take place, and the roles and responsibilities of individuals within the learning community (Fischer et al., 2013). Whereas *scripting* refers to the structuring of activities before they are run, *orchestration* refers to the process of executing a curricular script once the activity has already begun (Dillenbourg, 2015). Several researchers (e.g. Rodríguez-Triana, Martínez-Monés, Asensio-Pérez, & Dimitriadis, 2015) have recognized that LA can play an important role in supporting students' and teachers orchestrational decision-making throughout the enactment of CSCL scripts. We have developed such a script, including both student- and teacher-facing LA representations of progress, to investigate the research questions above.

Methodology

This study is part of a broader design-based research project, wherein we worked closely with a high school biology teacher to co-design a KCI curriculum and corresponding technology environment called *CKBiology*. In this paper, we report on data collected during the third design iteration of CKBiology, which entailed one curricular unit of a Grade 12 Biology course, on the topic of Homeostasis, that was implemented in a blended learning environment over a 10-week period during the 2016-2017 academic year.

Research context, participants and sampling

This research was conducted at a university laboratory school in a large urban area. Activities took place within two contexts: (1) In a traditional science classroom with a "bring your own device" (BYOD) policy, and (2) in a technology-enhanced Active Learning Classroom, which was constructed by the school with the explicit aim of fostering productive collaborations between students (see Figure 1b). A purposeful sampling approach was used to select the teacher participant. Selection was based upon the teacher's prior experience in KCI research as well as her availability to design and implement a KCI curriculum during the 2016-2017 academic year. The students who participated were an incidental sample in that they were those who happened to be assigned to the classes of our co-design teacher in two sections of a Grade 12 Biology course (n=28).

CKBiology activity structure

There were two types of activities in CKBiology: *Lessons* and *review challenge* activities. The lesson activities complemented traditional classroom lectures, and were performed by students within their regular science classroom using their own devices. There were eight lesson topics throughout the Homeostasis Unit, which were taught over multiple days. Each of these lesson topics was visible on students' CKBiology home screens (see Figure 1a), with activities enabled sequentially by the teacher as they were taught. Following each lecture, students logged on to CKBiology and selected the corresponding lesson activity, where they were assigned three different types of tasks. The first type of task was to *define terms or concepts* related to that day's lesson. The list of terms associated with a given lesson was established in advance by the co-design team based on the learning goals for the lesson. Concepts to be defined were divvied up evenly among students in the class. Students' definitions for these terms were contributed to the community knowledge base in the form of text-based notes with optional images (see Figure 2). The second type of task was to *identify relationships between terms or concepts* in the knowledge base. Within the CKBiology interface, students were presented with two terms separated by a drop-down list of relationship types. In this case, there was actually a "correct relationship" between each pair of terms, established in advance by the co-design team and programmed into the software. If a student chose the correct relationship, a line would appear connecting the two terms in the knowledge base. The relationship would also appear as a sentence within each note involved in the relationship. For example, the sentence "lysozyme *is a type of* antimicrobial protein" would appear in both the "lysozyme" note and the "antimicrobial protein" note. The third and final task was to *peer review or "vet" definitions* that had been submitted by other students in the learning community. Within the CKBiology interface, students were presented with an anonymized definition followed by the prompt: "Is this explanation complete and correct?" If the student responded "yes" to this prompt, that student's name would be appended to the note along with the statement "This explanation is complete and correct." If the student responded "no" to the prompt, a text box and image uploader would appear beneath the original note, and the student would be asked to add any new ideas and/or corrected information. Any additional information entered by the student would be appended to the original note along with the student's name. Subsequent vets performed on that note would also include this appended information.

Following the lessons, there were two CKBiology *review challenge* activities, completed by small groups of students within the Active Learning Classroom, whose purpose was to help students apply their knowledge to "real-world" inquiry problems. In the first review challenge activity, students selected an area of specialization (i.e. immunology, endocrinology, nephrology, and neurology) and worked within their specialist groups to solve a series of problems in order to become 'certified' in their chosen specialization. In the second review activity, students formed jigsaw groups (i.e. "medical clinics"), consisting of one representative from each specialization. Playing the role of medical practitioners, students had to bring together their diverse expertise in order to diagnose a virtual patient with ambiguous symptoms. This included ordering the appropriate lab tests, explaining the reasoning behind their diagnosis, and identifying possible treatment options—thereby consolidating the knowledge they had acquired throughout the unit. In both review challenge activities, a series of scaffolded questions were presented to students in CKBiology using a shared group display, and responses were entered by different group members using a wireless keyboard.

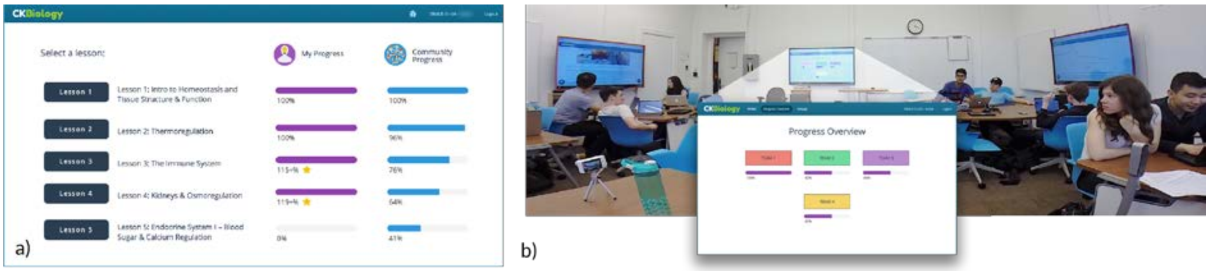
Materials: Representations of progress in CKBiology

1. Progress Bars. There were three kinds of progress bars used in CKBiology: Individual progress bars, group-level progress bars, and community-level progress bars. *Individual progress bars* were used for CKBiology lesson activities and were visible to individual students on their home screen beside each lesson activity (see Figure 1a), and at the top of the students' screens as they progressed through their CKBiology lesson tasks (i.e. explaining terms, identifying relationships, and vetting other students' definitions). The number of tasks assigned to each

student was calculated by dividing the total number of concepts, relationships, and vets by the total number of students in the class. The knowledge base was considered 'complete' when all of the terms had been defined, all of the relationships had been identified, and when each definition had been vetted at least twice. While the number of tasks assigned to a student varied from lesson to lesson, on average students were assigned five explanations, five relationships, and 30 vets per lesson throughout the Homeostasis unit. If a student achieved 100% progress, they would have the option of going "above and beyond" their assigned work to make additional contributions, earning themselves a *gold sta*r (described below) and additional progress points above 100%. These additional contributions typically took the form of extra vetting tasks and did not detract from the assigned work of other students. In this sense, no individual student could dominate the knowledge base (e.g., by defining all terms and relationships), and every student was still held accountable for making their fair share of contributions.

Community-level progress bars appeared on students' home screens immediately to the right of their individual progress bar (Figure 1a). These were expressed as a percentage, with 100% being achieved if all students completed their minimum number of assigned tasks. Students who chose to go "above and beyond" their own assigned work by performing additional vetting tasks could increase community-level progress; however as long as there were students who did not contribute their fair share, community progress could never reach 100%.

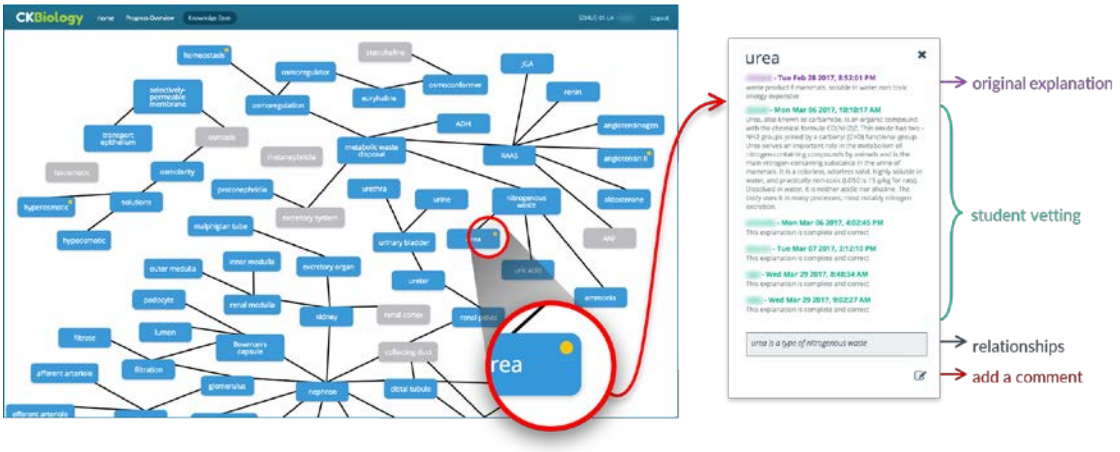
Group-level progress bars were used for the review challenge activities only, and were displayed on a large screen at the front of the Active Learning Classroom while students were working (Figure 1b). The group-level progress scores represented the proportion of challenge questions that each group had completed. While all three types of progress bars served to represent the *quantity* of work that students had completed, other features of CKBiology allowed assessment of the *quality* of students' work (e.g. vetting, commenting, and review reports).



Select a lesson:

		My Progress	Community Progress
Lesson 1	Lesson 1: Intro to Homeostasis and Tissue Structure & Function	100%	100%
Lesson 2	Lesson 2: Thermoregulation	100%	96%
Lesson 3	Lesson 3: The Immune System	115% ★	76%
Lesson 4	Lesson 4: Kidneys & Osmoregulation	119% ★	54%
Lesson 5	Lesson 5: Endocrine System I – Blood Sugar & Calcium Regulation	0%	41%

Figure 1. (a) Student home screen showing individual progress bars (purple) and community-level progress bars (blue) for each lesson. (b) Group-level progress bars publically displayed in the Active Learning Classroom.



- Tue Feb 28 2017, 8:52:01 PM

- Mon Mar 06 2017, 10:10:17 AM

- Mon Mar 06 2017, 4:02:45 PM
This explanation is complete and correct

- Tue Mar 07 2017, 3:12:10 PM
This explanation is complete and correct

- Wed Mar 29 2017, 8:48:34 AM
This explanation is complete and correct

- Wed Mar 29 2017, 9:02:27 AM
This explanation is complete and correct

urea is a type of nitrogenous waste

Figure 2. Community knowledge base (left side) and explanation note (right side). Explanations containing incomplete or incorrect information as a result of student vetting are indicated with a yellow dot.

2. Gold stars. The gold star representation was used for CKBiology lesson activities. When students achieved 100% progress for their work on a given lesson, they received the message: "Thank you for completing your submission! Would you like to continue contributing your knowledge to the community?" If the student chose "yes," a gold star icon would appear beside their individual progress bar (see Figure 1a), and the student would earn additional progress points for each additional task they completed. It was up to the student to decide how much more they wished to contribute—the limiting factor being the availability of notes that had neither been authored nor previously vetted by them. The gold star icon itself was visible only to the individual student,

however the teacher was able to see students with progress scores above 100% from her teacher dashboard (i.e. no gold star was present there).

3. Community knowledge base. For each lesson, students' contributions to CKBiology were aggregated into a shared community knowledge base, which was visible to all members of the learning community. As shown in Figure 2, concepts and terms with completed definitions appeared in blue and those that had not yet been defined appeared in grey. This feature of the representation enabled all community members to see at a glance where gaps existed in the knowledge base. Clicking on a blue term would open the corresponding note, including the original definition and author, followed by any vetting, images (if present), relationships, and comments (if present). Terms that appeared in grey were un-clickable, and the students assigned to those terms were not directly identified. Within the knowledge base, a yellow dot was used to identify notes that had been deemed 'incomplete' or 'incorrect' as a result of student vetting. This yellow dot served as a cue to the teacher to take a closer look at these notes and potentially initiate a follow-up discussion to negotiate or improve upon these ideas as a class.

4. Teacher dashboard. For the CKBiology lesson activities, the teacher dashboard displayed each individual student's progress score, ordered from highest to lowest (see Figure 3a). The teacher could also view the community-level progress bar for each lesson, and could toggle to and from the knowledge base. For the review challenge activities, the teacher dashboard included the group progress overview—the same as was displayed publicly for the students. From the group progress overview screen, the teacher could click on any group's name and pull up their "review report" (Figure 3b), which displayed the group's responses in real-time as they progressed through their review challenge questions. These responses were color-coded to correspond to the group member (i.e. specialist) who completed the response. The teacher could then use this information to decide when and where to intervene throughout the activity, and to better tailor her support to each group.

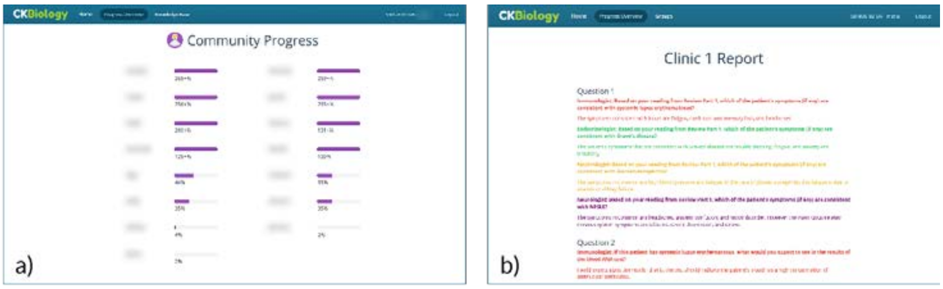


Figure 3. Teacher dashboard examples. (a) Progress overview screen, showing the individual progress of each student; (b) Review report, showing real-time responses for a group completing a review challenge activity.

Sources of data

To assess how each of the aforementioned representations was used within the learning community, data was triangulated from the following sources:

Student questionnaire. Students were given a questionnaire using Google Forms, which they completed after their final review challenge activity. The questionnaire consisted of 16 items, which were formatted using a five-point Likert scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). Several of the item stems were drawn from the "awareness" and "impact" dimensions of the Evaluation Framework for Learning Analytics (EFLA v4; Scheffel, 2017). For questions referring to each kind of representation (i.e., progress bars, gold stars, etc.), an image of the representation was included immediately preceding the corresponding items. At the end of the questionnaire, students also had the option of submitting open-ended comments. In total, 19 students completed the questionnaire and six students submitted additional comments. *Sample questionnaire items for Individual progress bars:* This representation makes me aware of my current level of progress; The fact that my level of progress is visible to the teacher motivates me to increase my progress, if necessary. *Sample items for the Gold Stars:* The ability to earn a gold star motivates me to increase my progress if I've already reached 100%. *Sample items for Community Progress bars:* This representation makes me aware of the level of progress of the whole class; This representation motivates me to contribute further, if below 100%. *Sample items for Group Progress bars:* This representation allows my group to see when other groups are stuck; This representation motivated me to contribute further, if below 100%. *Sample items for the Community Knowledge Base (Concept Map):* This representation accurately captures all of the important terms/concepts for a given lesson; This representation makes me aware of any gaps in the knowledge base.

Teacher interview. A semi-structured interview with the teacher was conducted following the final review activity. The interview was structured around four images, which were discussed in turn: (1) The individual student progress overview, (2) the group-level progress overview, (3) review reports, and (4) the community knowledge base representation. The initial prompt for each of these images was "Within the context of a learning community, how useful was this representation to your practice?" with follow-up questions emerging from the resulting discussion. The interview was audio-recorded and transcribed, and lasted approximately 30 minutes in duration.

CKBiology log data. Two types of log data were used for this study: (1) Students' individual progress scores for each lesson, and (2) students' gold star earnings. Only data from the Homeostasis Unit was analyzed. Additionally, only the first seven of eight lessons were included in the analysis; the final lesson was excluded due to an adjustment in the code that artificially boosted students' progress scores.

Results and discussion

Progress bars

There were two student questionnaire items included for all progress bar representations: (1) An "awareness" item (i.e. "This representation makes me aware of [my/my group's/the community's] level of progress"), and (2) A "motivation" item (i.e. "This representation motivates me to contribute further, if below 100%. The responses to each of these items are shown in Figure 4 below.

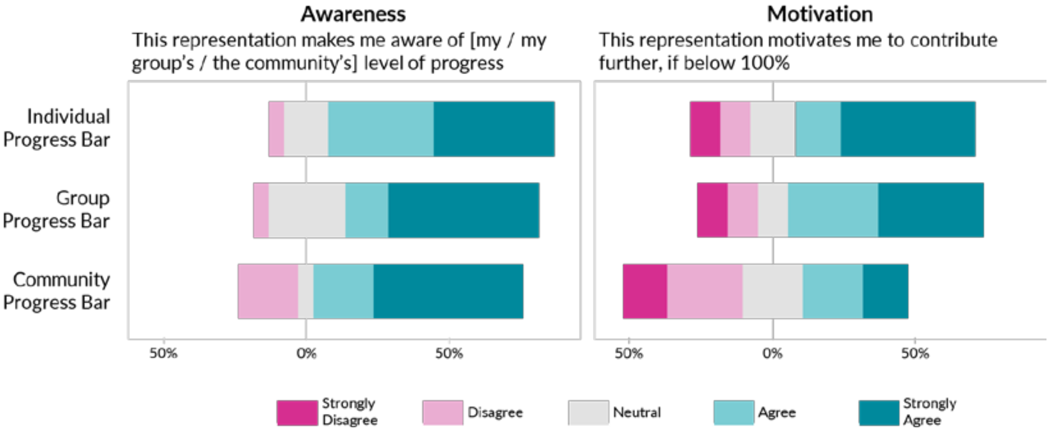


Figure 4. Students' perceptions of the individual, group, and community-level progress bars with respect to their "Awareness" (left side) and "Motivation" (right side).

We performed a Friedman test to identify significant differences in students' perceptions of the individual, group, and community-level progress bars with respect to their "awareness" and "motivation" ratings. While the Friedman test did not reveal any significant differences among students' "awareness" scores, significant differences were identified for students' "motivation" scores, $\chi 2$ (2, N=19) = 8.55, $p < .05$. In order to identify which pairwise comparisons were significant, we performed a post-hoc Conover-Iman test on the "motivation" data, including a Bonferroni correction. Results indicated that there were no significant differences in students' ratings between the individual and group-level progress bars, however the community-level progress bar was rated significantly lower than both the individual and group-level progress bars (both $p<0.001$). These results suggest that students felt significantly less motivated to make contributions to the learning community when they saw that the community-level progress bar was below 100% than they did when their individual progress bar or their group's progress bar was below 100%.

Data concerning the context and visibility of these representations provides further insight on student motivation. For example, 79% of students agreed or strongly agreed with the statement, "The fact that my level of progress is visible to the teacher motivates me to increase my progress, if necessary." This suggests that the teacher's role as an evaluator of students' work maintained a heavy influence, even within a context of collective cognitive responsibility (Scardamalia, 2002). The values of a learning community were in direct conflict with students' inclination to focus on competitive, merit-based aspects of schooling, including university applications.

Gold stars

Only 42% of students agreed or strongly agreed with the statement, "The ability to earn a gold star motivates me to increase my progress if I've already reached 100%." The CKBiology log data revealed that an individual student's gold star-earning behavior did not change very much from lesson to lesson: The students who earned a gold star in Lesson 1 (Group A, n=12) tended to remain gold-star earners, while students who did not earn a gold star in Lesson 1 (Group B, n=16) tended to remain non-gold star-earners. A Welch's two sample t-test was performed to compare the difference in the number of gold stars earned by these two groups. Results indicated a significant difference in the mean number of gold stars earned by Group A (M=4.2) and Group B (M=0.12); t = –6.9509, p < .0001. Thus, if a student did not earn a gold star in Lesson 1, they were unlikely to earn a gold star in any of the subsequent lessons. Using the same two groups, we compared students' mean progress scores for all seven lessons. A Welch's two sample t-test revealed a significant difference in the mean progress score for Group A (M=119.9) and Group B (M=87.3); t = –3.2741, df = 19.268, p < .01, with students in Group A having a 32.6% higher mean progress score than students in Group B.

Knowledge base representation (concept map)

Sixty-three percent of students agreed or strongly agreed with the statement that the knowledge base accurately captured all of the important terms/concepts for a given lesson. In the "additional comments" field on the questionnaire, one student wrote: "*There were many terms included that were only circumstantially related to the unit.*" In her interview, the teacher also commented: "*I think we need to trim the number of terms because it's just too many. So, I think we should focus more on the basic ones… But that is not something that we would have known going in. Like, this is something that I am actually reflecting now that I went through it.*" The teacher also commented that it would be helpful to have two different kinds of vetting dots—one for when an explanation is incomplete and another for when an explanation is incorrect: "*Because many times I went into the yellow dots and there was no conflict. There was just, like…somebody put half the definition and then the second person put the second half of the definition, and then a third person came in and said 'oh wait a minute, and these are examples of blablabla,' which I thought was great… And then you can take it up in different ways.*"

Teacher dashboard

In her interview, the teacher commented that the lesson progress overview screen was "*very useful because it made very clear what was happening.*" In using the progress overview screen as part of her workflow, the teacher would look for progress scores that she felt were of concern, and would then delve deeper into those students' work. For example, if she saw a student with an exceedingly high progress score (e.g. in comparison to other students, or to past behavior), she would check the knowledge base to make sure that the student's explanations weren't overly superficial or had been flagged as "incomplete" or "incorrect" by other students. Conversely, if she noticed that a student who was typically a high achiever had a low progress score, she would follow up with the student to see what was happening. Regarding the review challenge reports, the teacher commented: "*That was really nice. I like the color-coded because it was easy to follow who was doing what. So, I liked them. It was clear. I'm very visual, I think…colors help me.*" The teacher indicated that she would mostly use the review reports to check the answers of groups who claimed they were finished: "*So ok, these people are done, so I'm going to go see their answers. Then I would go and check 'ok, so no - this is not great' 'mmm, this needs to be looked after.' Then I would go back to them and say, 'did you consider blahblahblah.'…And that's how I used it.*"

Implications and next steps

This study represented our first effort to infuse KCI curriculum and technology environments with learning analytics. To begin, we chose relatively straightforward functions of progress representation because of their familiarity to students and potential impact on helping the community make decisions in response to this information. The experiences in designing and evaluating these features will guide our future efforts, as we add more 'hidden' layers of learning analytics, such as tracking groups' interests and sending materials or prompts based on contextual information. We can also use more nuanced group analytics to determine when a group might need input from the teacher, and send the teacher an active notification in real time. This active form of tracking and notification contrasts with the ambient role of progress representations employed in the present study.

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