Increasing Teacher Productivity and Participation in Curriculum Development Via a Customized Content Management System

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Purpose

The national “CS10K” effort supported by the National Science Foundation (NSF) has aimed to increase the quality, diversity, and number of computer science (CS) high school teachers in the United States, and in turn, broaden the participation of diverse high school students in computing classes. The goals are for the CS education teacher community to mirror the student populations of the United States demographically (Ladson-Billings, 2005) and (originally) to have ten thousand teachers in ten thousand schools across the United States by 2015 (Astrachan, Cuny, & Stephenson, 2011). One particular method to build this teacher capacity was to offer a new computer science course called Advanced Placement (AP) Computer Science Principles (CSP), enabling a diverse population of high school students to take a college-level course (College Board, 2014). New curricula needed to be developed for the course, as well as professional development opportunities for the new CS teachers. Under an NSF grant, the “CS Matters in Maryland” version of the AP CSP course was created (and is continuing to be refined) using a collaborative curriculum development process. The challenge was not only to align the curriculum with the College Board framework for the course, but also to align it with the increasing lists of standards (Next Generation Science Standards, Common Core, Computer Science Teachers Association standards, state-level mandates and policies, etc.). To meet this challenge, a new customized content management system called the Collaborative Curriculum Creation System (C3S) was developed and a curriculum development project team that included CS university faculty and CS high school teachers was assembled to create curriculum for the AP CSP course.

Theoretical Framework

The theoretical framework for this project consists of building a community of practice (CoP) of CS educators and drawing upon literature from military, business, and government research on small group interactions to streamline the workgroup processes during curriculum development. The overall goal was to increase productivity and group members' participation in the curriculum development process. In order to build upon the national effort to increase the number of CS teachers, a community of practice (CoP) was established at the national level through the Computer Science Teachers' Association (CSTA). By chartering a local state chapter and organizing a series of statewide meetings, the project team began to facilitate communication across the state among in-service CS teachers, CS school system supervisors, principals, and interested local business representatives.

Unlike other content departments in high schools, which usually consist of several teachers in subject areas such as science or mathematics, most schools have at most a single CS teacher, who often also teaches classes in other subject areas such as mathematics, science, or business. Also, a CS teacher may be expected to provide information technology assistance at the school level. Unfortunately, the isolation of many CS teachers can lead to further departmental identity issues, depending on the department (business, mathematics, science, etc.) in which the school places the CS teacher (Ni & Guzdial, 2012). The curriculum development project was another step in the growth process and community building of the local CoP of CS educators by bringing them together out of the isolated schools to create the new AP CSP course. Attention was paid to encourage geographic, gender, and ethnic diversity in order to strengthen the CoP with diverse *newcomers* and to create curricular products that appeal to diverse audiences with participation from all of the curriculum development team members (Lave & Wenger, 1992;

Wenger, McDermott, & Snyder, 2002). This type of community building during a collaborative curriculum design process has also been shown to provide teachers with agency (voice) during the process and continued professional development growth (Voogt, Laferriere, Breuleux, Hickey, & McKenney, 2015). Once the team members were assembled, the workflow processes for curriculum development were established.

Workflow Processes

Although curriculum development is strengthened with the participation of teachers, teachers are not always comfortable editing the lessons of other teachers and communication between researchers and teachers during development is often strained (Garvin & Steiff, 2009; Penuel, Coburn, & Gallagher, 2013; Reiser et al., 2000). Each subgroup was carefully selected to increase the diversity within each group in order to increase individual member participation (van Knippenber & Schippers, 2007). To further mitigate this problem, instead of reserving editing as a final step after all lessons were written, editing occurred throughout curriculum development, which created a robust writing and revising process that continuously engaged all of the team members.

The curriculum development team divided the fifteen CS teachers into different roles and subgroups. Each subgroup was assigned two units and tasked to develop a specific number of 50-minute session lessons for given topics. Task roles included specific writing and editing tasks (Bales, 1950), and leadership positions were assigned to three “lead CS teachers” who filled boundary-spanning roles between subgroups (Mumford, Campion, & Morgeson, 2006). Each CS teacher was assigned both writing and editing roles within the C3S. (See Figure 1.) Each lesson was edited separately by different project members for the following: Readability and Presentation, Common Core Alignment, CSP Objective Alignment, Differentiated Instruction, Active Pedagogy, and College-Level Rigor. Each editor had specific guidelines to edit the lesson for the given editing process. Editors were permitted to make minor edits as needed; however, if more significant clarification or edits were required, the lesson was assigned back to the author. Load balancing of work was maintained by the lead teacher of the subgroup for writing and by the curriculum research associate and CS professors for editing.

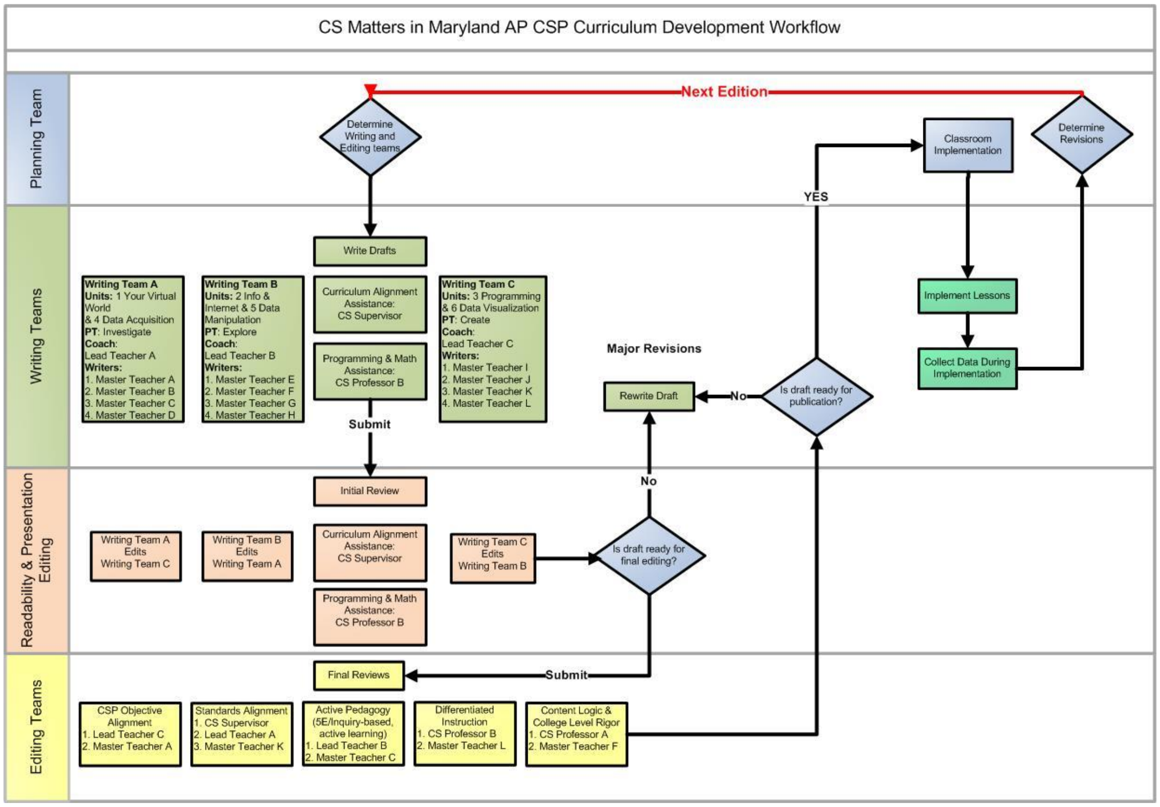

Figure 1: The workflow process used to create the CS Matters AP CSP curriculum.

Methods

The planning process for the CoP was extensive and began with an initial planning team. This core team included three CS high school lead teachers, two CS university faculty, and one STEM education research associate. Teachers from across the region were invited to apply to become members of the curriculum development team. The planning team carefully considered each candidate and specifically searched for qualified CS high school teachers. Members were selected based on overall teaching experience, CS teaching experience, geographic locations in the state, and prior curriculum development experience. (See Table 1.) After selection to the curriculum development team, university team members visited the classroom of each master teacher to observe the classroom, discussed the project in more detail with the teacher, and met with the school principal to answer any questions that he/she had about the project. In all, the curriculum development team consisted of fifteen CS high school teachers (representing nine different regional school districts), two CS university faculty, one CS local school district supervisor, and one STEM education research associate. Several undergraduate and graduate students from the University of Maryland, Baltimore County (UMBC) also assisted and supported the team throughout the curriculum development process.

CS Matters Lead and Master Teachers				
Team Member	**Label**	**Gender**	**Ethnicity**	**Years of teaching experience**
Lead Teacher A	LTA	F	Caucasian	12
Master Teacher A	MTA	F	Caucasian	11
Master Teacher B	MTB	M	African American	34
Master Teacher C	MTC	F	Caucasian	12
Master Teacher D	MTD	F	Caucasian	16
Lead Teacher B	LTB	F	Caucasian	20
Master Teacher E	MTE	F	Caucasian	15
Master Teacher F	MTF	M	Caucasian	21
Master Teacher G	MTG	M	Caucasian	13
Master Teacher H	MTH	M	Caucasian	11
Lead Teacher C	LTC	M	Caucasian	35
Master Teacher I	MTI	F	Caucasian	36
Master Teacher J	MTJ	F	Caucasian	15
Master Teacher K	MTK	F	Caucasian	2
Master Teacher L	MTL	F	African American	14

Table 1: The CS Matters Lead and Master Teachers who wrote and edited the curriculum for the AP CSP course

The curriculum development team first assembled for a full day face-to-face meeting on Saturday, March 29, 2014. The team reviewed the AP CSP framework and worked together to review existing CS materials that might be used as resources during the curriculum development in the summer. Each lead and master teacher selected activities to teach before the end of the school year. The initial C3S was introduced to the team and modified based on the feedback from the team members.

Collaborative Curriculum Creation System (C3S)

The C3S was created to facilitate the curriculum development process. The C3S consists of an online database containing all of the lessons and a front-end website featuring a password-protected interface for writing and editing the content. Each lesson iteration is captured when the changes are saved, and the entire history of each lesson is permanently stored in the database. The C3S tracks who has made the lesson modifications and which editing process was completed.

The web interface provides writers with three primary actions: add or edit specific information for each lesson, view the curriculum development summary, and export the lessons. Lesson components include general information (unit, lesson title, who is assigned, status of completion), lesson summary, check boxes for lesson objectives (College Board) and standards (Common Core Mathematics, Common Core English Language Arts, NGSS practices, and NGSS content), key concepts, essential questions, teacher resources, lesson plan content, evidence of learning (formative and summative), and curriculum development status (pending tasks, future work, and editing comments) (Figure 2). As shown in Figure 3, the summary page provides the curriculum development team with three overviews: lesson completion, course objectives covered, and aligned standards. Each view provides the entire team with a visual overview of what topics are well covered, how often each is covered, and any areas that still need development. Finally, the interface extracts the current state of the curriculum from the database as a complete export or as a collection of units at any stage of the process. This functionality allows the team to create a snapshotted version of the curriculum to use publicly while ongoing development occurs privately within the C3S (Figure 4).

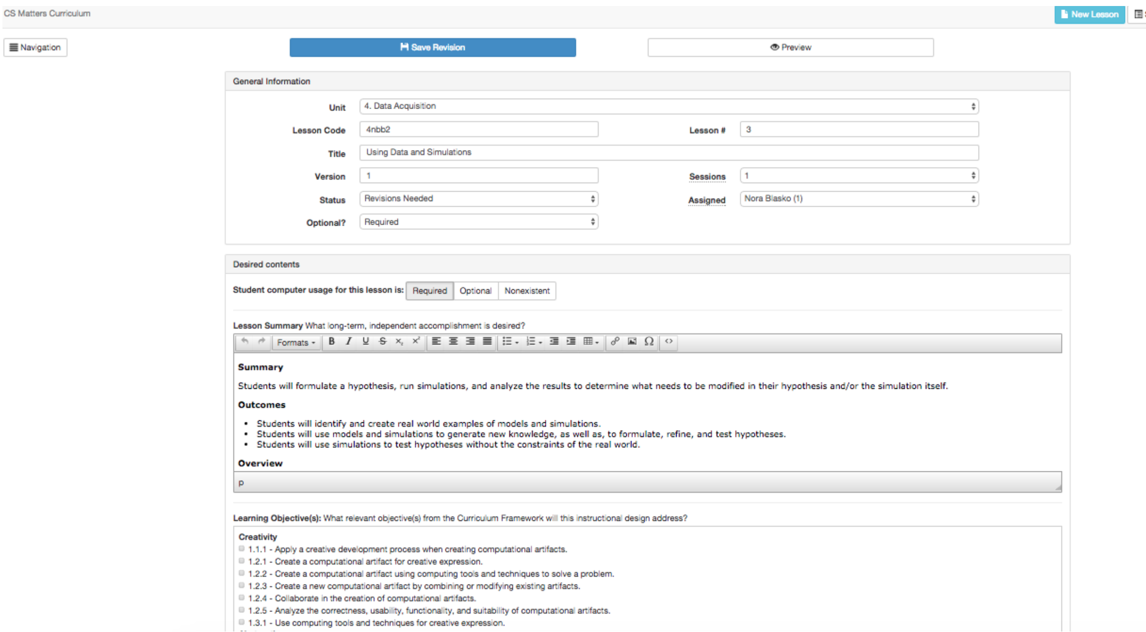

Figure 2: This is the lesson writing and editing page in the web interface.

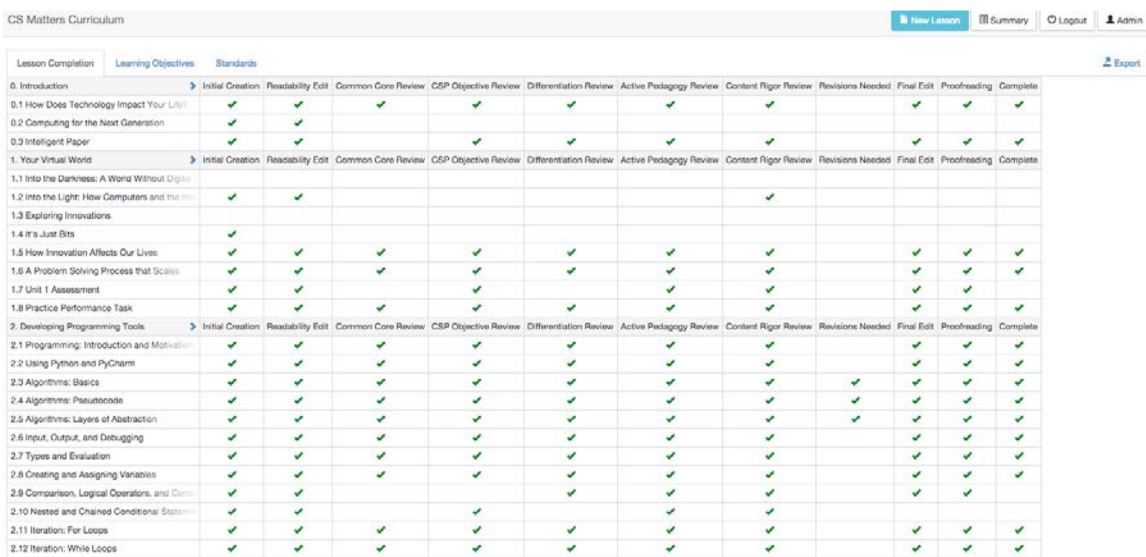

Figure 3: The lesson completion summary page in the web interface provides views for the lesson completion status, learning objective coverage, and the standards coverage.

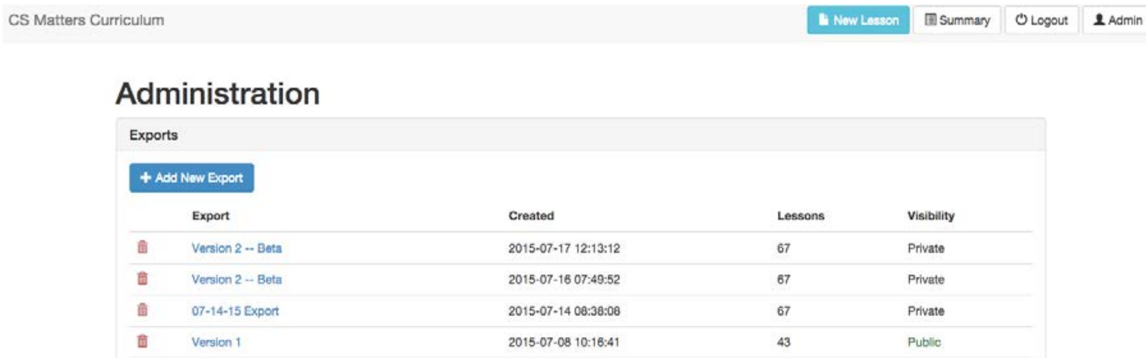

Figure 4: This is the export page in the web interface.

The C3S is also customized to capture and analyze data about the curriculum and the development process (Figure 5). Individual and group productivity was measured by the performance output of productivity in terms of time spent on specific tasks and edits made by team members (Cohen & Bailey, 1997). The C3S tracked and verified the workflow process and load balancing of tasks across group members.

Table	Engine	Collation	Data Length	Index Length	Data Free	Auto Increment	Rows	Comment
active_lessons	InnoDB	utf8_unicode_ci	16,384	49,152	1,286,602,752	159	~ 103	
exports	InnoDB	utf8_unicode_ci	16,384	0	1,286,602,752	23	~ 22	
export_items	InnoDB	utf8_unicode_ci	114,688	147,456	1,286,602,752	1,382	~ 1,338	
export_passwords	InnoDB	utf8_unicode_ci	16,384	0	1,286,602,752	66	~ 54	
lessons	InnoDB	utf8_unicode_ci	491,520	507,904	1,286,602,752	4,137	~ 4,227	
lesson_data	InnoDB	utf8_unicode_ci	74,022,912	3,178,496	1,286,602,752	61,047	~ 55,595	
lesson_list_items	InnoDB	utf8_unicode_ci	49,152	0	1,286,602,752	188	~ 139	
lesson_statuses	InnoDB	utf8_unicode_ci	16,384	0	1,286,602,752	13	~ 12	
migrations	InnoDB	utf8_unicode_ci	16,384	0	1,286,602,752		~ 24	
names	InnoDB	utf8_unicode_ci	16,384	16,384	1,286,602,752	1	0	
password_reminders	InnoDB	utf8_unicode_ci	16,384	32,768	1,286,602,752		0	
sessions	InnoDB	utf8_unicode_ci	49,152	0	1,286,602,752		~ 75	
units	InnoDB	utf8_unicode_ci	16,384	16,384	1,286,602,752	10	~ 9	
users	InnoDB	utf8_unicode_ci	16,384	16,384	1,286,602,752	28	~ 27	
wiki_logins	InnoDB	utf8_unicode_ci	16,384	16,384	1,286,602,752	243	~ 242	
wiki_pages	InnoDB	utf8_unicode_ci	16,384	16,384	1,286,602,752	2	~ 1	
wiki_revisions	InnoDB	utf8_unicode_ci	16,384	16,384	1,286,602,752	9	~ 8	
wiki_roles	InnoDB	utf8_unicode_ci	16,384	0	1,286,602,752	3	~ 2	
wiki_users	InnoDB	utf8_unicode_ci	16,384	16,384	1,286,602,752	3	~ 2	
19 in total	InnoDB	latin1_swedish_ci	74,956,800	4,030,464	0			

Figure 5: The administrator view of the database for better control for selected advanced users.

Curriculum Development Phase I

The curriculum development team assembled for two summer workshops (June 23, 2014 to June 27, 2014 and July 27, 2014 to July 31, 2014). Team members were provided housing and meals; however, some members chose to commute daily. In between each summer workshop, all team members noted their availability in a spreadsheet, and they were not expected to complete tasks while they were unavailable (during vacations, other professional development activities, etc.). The team worked through the writing and editing processes remotely in the period between the workshops. The lead and master teachers returned to their classrooms and piloted the lessons while also refining and editing the lessons during the school year via the C3S.

Results

The subgroup autonomy during development empowered the CS teachers to work collaboratively to determine which lessons to develop, how to develop them, and the structure and formatting of lessons. This subgroup-based structure resulted in an increase in the overall productivity of the entire curriculum development team when compared with previous work which examined effectiveness and productivity of curriculum development groups (Garvin, 2012). The team wrote 71 lessons that covered 150 sessions (50-minutes per session) across seven units during a two-month period. As shown in Figure 6, groups created more initial lessons during the June and July workshops. The team worked through the writing and editing processes remotely in the period between the workshops with a slight increase in productivity just prior to the July workshop. The logical progression of fewer initial creation statuses was expected to occur throughout this first phase. In fact, workload was balanced between the editing and writing statuses as shown in Figure 7. As initial creation statuses decreased toward the end of the first phase, the editing and review statuses of lessons increased.

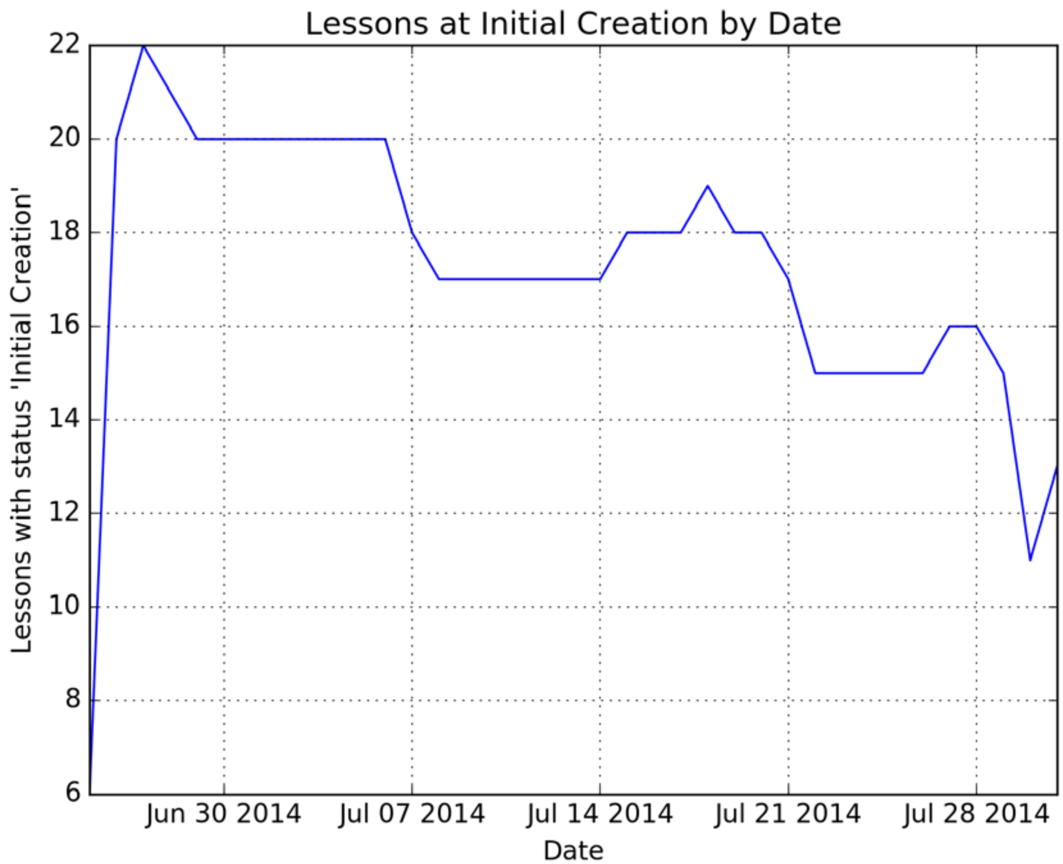

Figure 6: The number of lessons with the initial creation status during the first phase of curriculum development for the CS Matters AP CSP course changed during the face-to-face meetings from June 23, 2014 to June 27, 2014 and July 27, 2014 to July 31, 2014 and the time period in between when the team worked online.

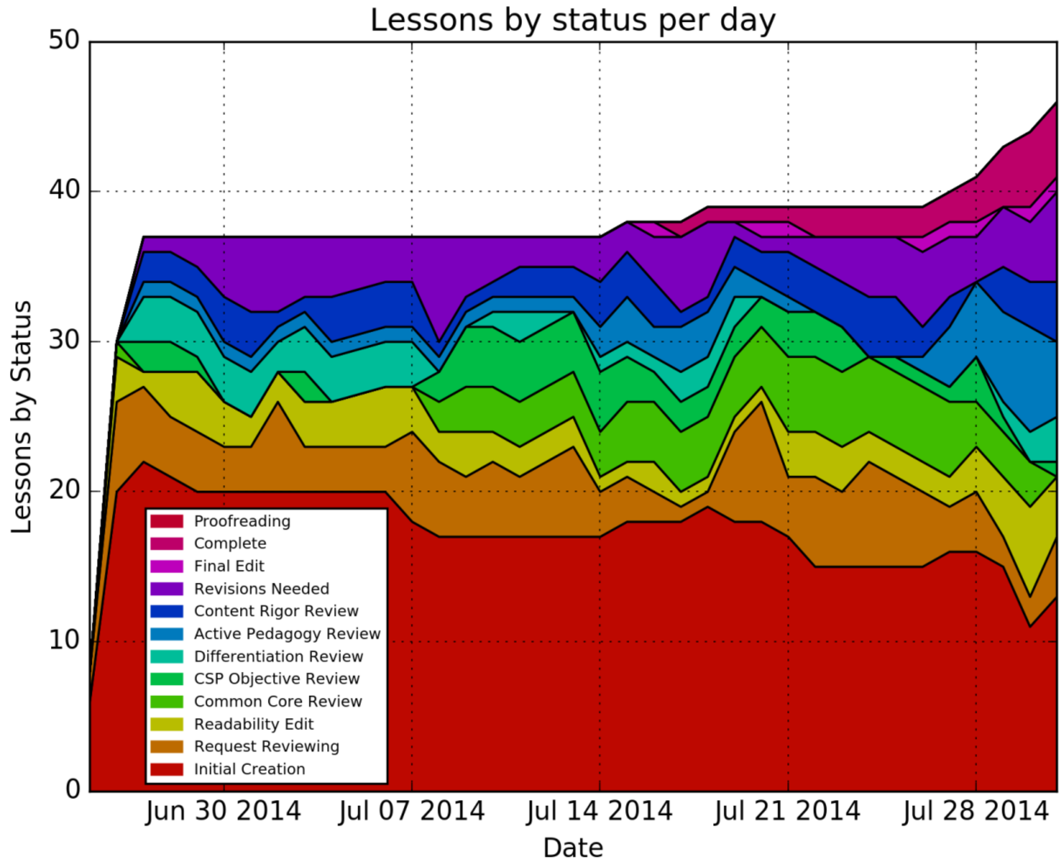

Figure 7: The amount of lessons within each status of lesson development per day during the first phase of curriculum development for the CS Matters AP CSP course. Writing and editing occurred simultaneously.

Productivity and Participation

Individual productivity was extracted from the C3S in several ways to analyze average workload for each day during the first phase. The average workload (tasks assigned) per person is the number of lessons that are assigned to a team member on that day, divided by the number of team members who are also working on that day while excluding team members with no assignments on that day. (See Figure 8.) The exclusion of members not working on each day is required to account for members’ time off due to other commitments or vacations. However, the "*Max per person*" indicates the most lessons any member had assigned to them on that day. This is used to compare to the average to see any unfair balances among team members. A large discrepancy between the max and the average shows that one or more members were assigned more tasks than the average member, showing an imbalance in assignments. A plateau in the max generally indicates that a user with the largest number of assignments continues to maintain their larger workload, and peaks and dips show an increase or decrease in assignments, respectively. In the beginning of the curriculum development, the workload was balanced across the team members, but by the end of the first phase, the workload became skewed. This is due to the number of members who participated in the end stage editing and reviewing processes and the task assignments that were directed to more productive team members who had availability to continue to work beyond the last face-to-face workshop.

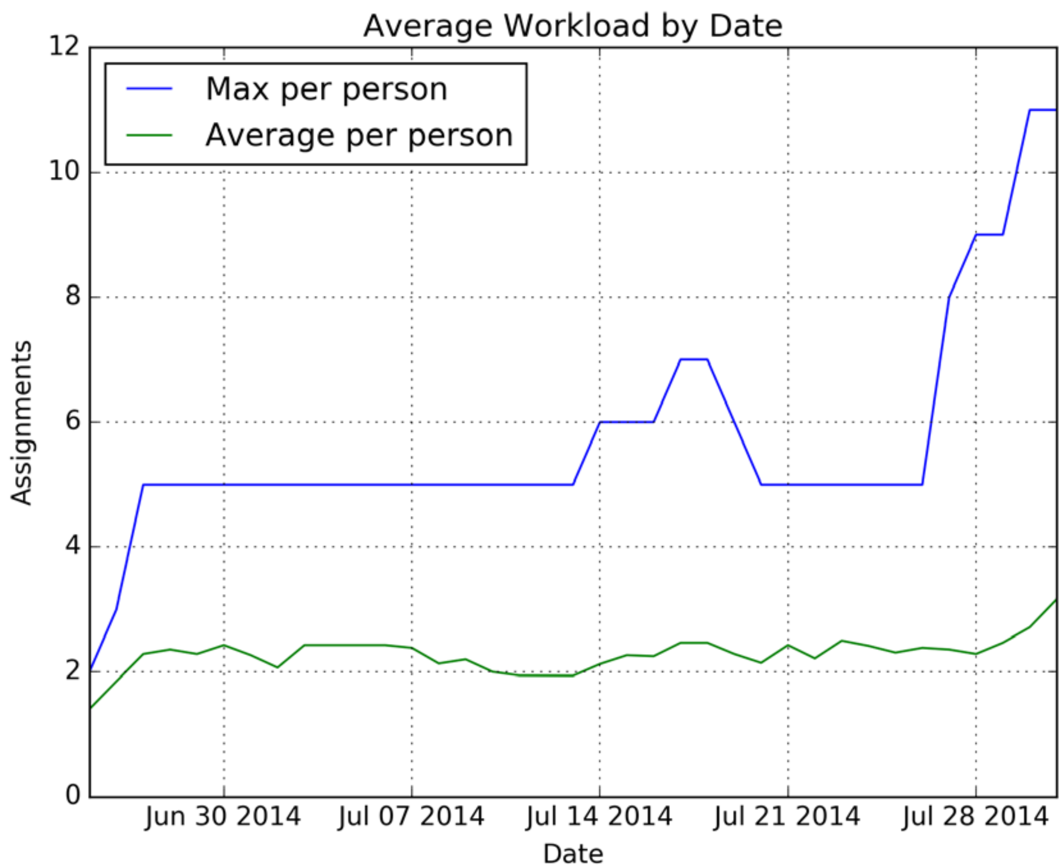

Figure 8: The average workload (assignments per number of team members assigned work) and maximum assignments for a member per day during the first phase of curriculum development for the CS Matters AP CSP course.

To further analyze the individual participation, the data captured in the C3S also showed the total edits within each lesson status for each team member during the first phase of curriculum development. Although all team members participated in writing and editing during the first phase, the total number of edits within each lesson status per person varied significantly across team members (Figure 9). However, this data also provides information into how each member utilized the C3S during this phase. Some members, such as LTA, MTD and MTL, spent more time within the initial creation status while writing lessons directly into the C3S; other members (MTA, MTE, MTF, LTC, MTJ, and MTK) wrote content in another application, placed the content into the C3S, and requested reviewing. Therefore, the number of edits in the initial creation does not equal the number of lessons that the member wrote; rather, it demonstrates whether the team member wrote lessons within the C3S or imported them. Also, important to note is the revisions requested lesson status. This status indicated that lessons were sent back to the author for suggested edits, and most team members had edits requested from other team members. The number of edits requested demonstrates the increase in the interactions across team members and between subgroups. This enabled team members to share concerns and suggestions throughout the first phase while minimizing members working in isolation. Within the subgroups, some group members worked more productively than other members, which was a function of workload efficiency and availability throughout the first phase.

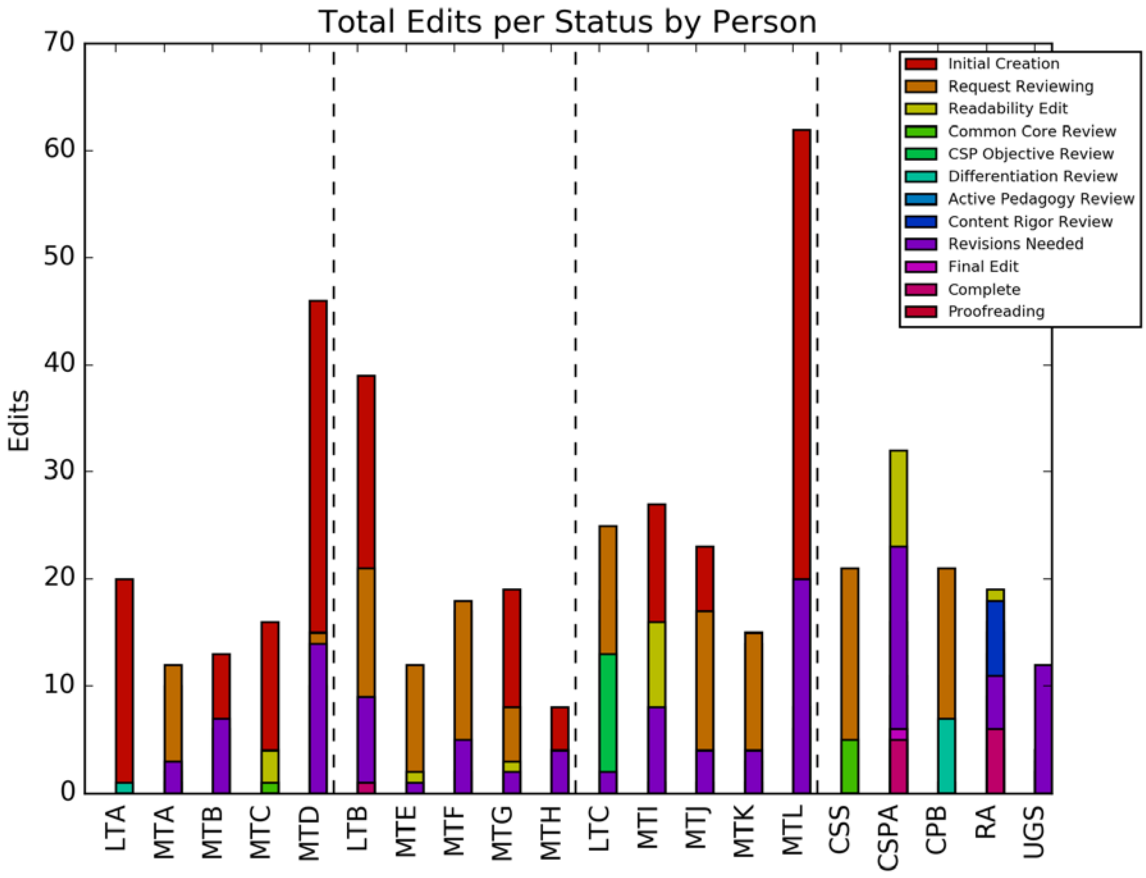

Figure 9: The total number of edits per person during the first phase of curriculum development for the CS Matters AP CSP course. Edits are grouped by the status of lessons that were edited, and members are grouped by writing and readability editing teams.

Conclusions

The CS Matters curriculum development team not only successfully built a CoP during the first phase of curriculum development, but the team also streamlined workgroup processes by utilizing the C3S. Both goals to increase productivity and team members' participation were met during the first phase of the AP CSP curriculum development process. The C3S enabled team members to develop the initial CS Matters AP CSP curriculum over two months. The system successfully enabled the team to track lesson statuses, AP CSP framework lesson objectives coverage, and various standards alignment. C3S also provided the team with the means to readily manage the project by assigning lesson statuses to team members and balancing workload across the team while also accounting for team member availability throughout the first phase. The C3S was designed as open source code and can be modified for customization to meet the needs of for future curriculum development projects.

Future Research

The C3S was continuously used during two more phases of the curriculum development process. Each additional phase included a new set of pilot teachers using the C3S to extract the lessons either as read only or through planned exports for updated versions of the curriculum. Further refinements to the lessons occurred by the planning team with input and suggestions made by the CS teachers who were teaching the AP CSP course. All of the history of the curriculum development is captured within the C3S and will be analyzed for each phase and across the entire project.

In addition to the C3S data, the planning team collaborated with external evaluators who routinely surveyed and interviewed project participants. The combined data sets will be used to examine additional workgroup processes such as group cohesion in order to strengthen our conclusions about the curriculum development process.

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