Concurrently Collaborative Spreadsheets in the Chemical Engineering Classroom

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Abstract

A project investigating the viability of a concurrently collaborative online spreadsheet to improve the effectiveness of student teams when solving chemical engineering problems is described. Students in two classes representing sophomores and seniors were assigned a problem to be solved using a spreadsheet on Google Docs, an online browser-based suite of productivity applications. The unique feature of this spreadsheet is that multiple users on multiple machines can edit the same spreadsheet simultaneously, with changes appearing on all users screen within about one second. Assessment was performed to determine whether use of this spreadsheet was technically viable, suitable for students not in the same room, and useful for improving the effectiveness and efficiency of students working in teams. From a limited sample size assessment, the Google spreadsheet does appear to be viable, to allow effective communication amongst participants, and to contribute to a more efficient and effective team problem-solving experience.

Keywords: spreadsheets, computing, collaboration, teamwork

Introduction

To prepare students for practice in the modern industrial world, graduates of chemical engineering degree programs are expected to function effectively in teams. At the same time, problem-solving skills are a focus, typically involving some computation. Often, these computations are completed with some computer software, with the most common type of software package used being a spreadsheet.

Collaboration on solving computational problems involving software has typically followed one of two models: participants gathered around a single computer with one individual interacting with the software; or a single computational file shared amongst multiple users, either from a common storage location or revision sharing via e-mail or other file transfer method. Neither method is efficient due to the need for reconciliation amongst edited versions or a limit of one concurrent editing session.

A new spreadsheet software, currently in beta status, is available from Google as part of its free Google Docs service. Google Docs is a web-browser based collection of office software (word processor, spreadsheet, and presentations) which is not operating system dependent, using Java to provide a rich user interface. The spreadsheet contains the key inline functions required for most chemical engineering problems, though it does lack other capabilities engineers frequently use in Microsoft Excel, such as Goal Seek, Solver, and advanced graphing functionality. Perhaps the most interesting feature of Google Docs is the ability to share a single online document amongst multiple users, and when configured appropriately, to enable simultaneous editing by multiple users.

Students in two chemical engineering courses were each assigned a different group problem for which they were expected to use the Google spreadsheet to solve. To prepare them for this process, they were given basic instruction in group problem solving, focusing on planning a solution and task distribution. Students then were placed in separate rooms and asked to create a spreadsheet solution using the online spreadsheet, using the built-in messaging software to communicate with teammates as needed. Students were observed by the instructor developing their solution, and the session was recorded from the perspective of an editor. The assessments of both the students and the instructor regarding the use of a concurrently edited spreadsheet will be presented, along with an overview of alternative approaches to collaborative computations using spreadsheets.

This paper was previously presented at the 2008 Annual Meeting of the American Society for Engineering Education.[1]

Background

The need to collaborate when using calculations to solve engineering problems is not new. Typically, collaborative problem solving in engineering courses means one of two things: students prepare a solution by huddling around a single computer while the person at the keyboard does most of the problem-solving; or students prepare portions of a solution and then gather to try to reconcile those contributions either in person or by sharing multiple computer files.

Many vendors of computational software have been working to address this need for teamwork by enhancements to existing software. Most attempts to add collaborative capability have followed one of two models.

- Library model. A single file is maintained with all calculations and associated documentation. When an individual accesses the document for editing from a central database, it is marked as unavailable. Multiple users can have simultaneous read-only access.
- Revision marking model. The software maintains an original document while incorporating changes the document into the file. An editor later has the option of accepting each change made by each author.

Each method has strengths and weaknesses. The library model is restricted to a single concurrent user. If a user fails to “return” the “borrowed” document, perhaps by failing to close the document, it is not available for editing without administrative action. The process of teamwork via this model forces a significant lag in the incorporation of ideas, since the review process is linear (write→review→revise→review→revise…) and often depends on the editing of a lead participant. The approach has the advantages of security (no changes will be lost under normal circumstances) and rapid accessibility of edited documents. It requires a server hosting the document library and managing access.

The revision marking approach is most common because it is decentralized (does not require a server host). Using this approach, changes are added to the document without deleting any information. Changes are coded to correspond to an individual editor. At some point, an individual may go through the document reviewing, accepting, and rejecting changes to the document. The final result may be the consolidation of the contributions of many individuals, but requires significant management by a single editor before the document is finalized. One key advantage is that all team members may edit the document simultaneously. The key disadvantage is that most team members will never see the suggestions of those whose contributions are rejected by an editor before they see a consolidated file. Another disadvantage to this approach it that at any given time there are multiple versions of a document file in existence, making it difficult to track which is the most current version.

Some approaches combine these methods, using revision marking on files managed by a central server.

This review focuses on the current state of collaborative functionality offered by companies offering computational software used by chemical engineers.

Desktop Applications

Microsoft. Microsoft offers several mechanisms to facilitate collaboration in its ubiquitous spreadsheet, Excel. It allows users to “Track Changes” (the revision marking approach) and add comments to facilitate contributions from multiple users. Additionally, Microsoft offers a server product known as SharePoint, implementing the library model. In addition to document management, it also provides services to enhance communication amongst users including “Wiki” style document writing, “blogs”, and persistent discussion forums. Some versions of Office (including the Enterprise version available through the campus licensing agreements at many universities) include Groove, a client-based program which offers some similar functionality to SharePoint but decentralized with less administrative effort. Finally, Microsoft has recently introduced its Live Office suite, which is a collection of web-browser based applications which mimic members of its office suite. Its spreadsheet equivalent, however, is currently not intended as a calculation tool.[2]

MathWorks. MATLAB, one of the most common math packages in use in chemical engineering departments, does not offer integrated collaborative functionality. However, since it is modeled after traditional development software, it does interface with industry standard source control software provided from other vendors. This is a library management approach with some revision tracking handled by the server.[3]

PTC. Mathcad offers user the capability to share worksheets including an edit-protected mode of “live” worksheets, but does not allow multiple users to edit a file in any non-trivial mode (other than providing a copy worksheet file to another user).[4]

Wolfram. Mathematica does not offer integrated collaborative functionality. The company offers a companion product, Wolfram Workbench, that serves as an integrated development environment (IDE) allowing multiple users to work on a development project. Individual files in that workspace may be edited by only a single user at a time.[5]

Maplesoft. There are no advertised collaborative features in Maple.[6]

OpenOffice.org. OpenOffice is a collection of open source projects oriented toward competing with the functionality of Microsoft Office. The Calc spreadsheet module does not offer native collaborative capabilities.[7]

Internet Based Options

Online Storage. There are multiple options available for engineers to use desktop applications on their desktop and store those files online for broader access. This includes services such as Xdrive (www.xdrive.com), Windows Live Folders (skydrive.live.com), Basecamp (www.basecamphq.com), WebOffice (http://www.weboffice.com), and Central Desktop (www.centraldesktop.com).[8] Some of these resources offer collaborative features using the library model, but the primary emphasis is that files are available from any location a user has network access.

Google. Google Docs (docs.google.com) offers a suite of web-browser based productivity applications (spreadsheet, word processor, presentations) that offer many of the standard capabilities of spreadsheets. For engineering purposes, it contains basic graphing capabilities, all standard functions and calculation capabilities. It does lack some features of particular use to engineers, including a “goal-seek” capability and circular (iterative) calculations. Another downside is a limit of 1MB for a single spreadsheet file. Documents may be imported from and exported to desktop applications, including Excel. The distinguishing feature of the offering is the ability to not only share documents with other users, but for all of those users to simultaneously edit the document with all changes appearing on the spreadsheet in nearly real-time. The application uses subtle outlines and color changes to indicate a cell is currently locked for editing by another user. Google currently does not charge individual users for access to the application.

Zoho. Google is not the only company to offer an online collaborative spreadsheet. Zoho (www.zoho.com) offers similar capabilities in what is arguably a more attractive package. A significant functionality recently added to Zoho is the ability to incorporate macro programs written in Microsoft’s Visual Basic for Applications syntax. Zoho is also free to individual users. The greater likelihood of a student already having a Google account led to the decision to use Google Docs in this project.

Objectives

This project was intended to investigate the practicality and effectiveness of using an online collaborative spreadsheets for small groups of chemical engineering students to solve problems.

In particular, we examined the following questions:

- Are online spreadsheets adequate for solving problems not requiring advanced spreadsheet capabilities?
- Are the communication capabilities of the online spreadsheet application sufficient for students unable to speak to one another to complete the solution?
- Does the requirement for network connectivity and use of a browser-based application significant impact the usability of a spreadsheet?
- Does the collaborative nature of the online spreadsheet contribute to training students to function effectively as a team?

Methods

To address these questions, students in two chemical engineering classes at the University of Kentucky Extended Campus in Paducah were each assigned problems to be solved as a team. One course consisted of a group of 5 sophomores in a material and energy balances class, and the other three students in a senior level engineering economy course. These sample sizes represent the total enrollment in this program at those levels. Students were given pre- and post-assessment surveys, with selected questions common to both surveys. The post-project survey included free-answer questions to illuminate student perceptions of their experience. Just prior to students being released to complete their assignments, they were given a 15-minute lesson on how to function as a team. Prior team training varied by student as indicated in the results. Students were observed moving to different locations in the engineering facility and were assumed to have followed the assignment requirement to not communicate outside of the application's instant messaging function.

The students in the sophomore course were given a problem requiring completion of a spreadsheet to calculate the compressibility of a mixture using the Peng-Robinson equation of state. Since registration is required to use Google Docs, students registered for the site a week in advance and added their name to a shared spreadsheet to confirm they had access to the spreadsheet. Students were to complete selected portions of the spreadsheet based on equations provided on the assignment sheet. The spreadsheet was color-coded to indicate cells the students should edit, and those cells representing inputs to the problem. A brief explanation of how to use the spreadsheet was given in the context of the spreadsheet they were going to edit, and the correspondence of the equations on the assignment sheet to the spreadsheet was explained. Finally, students were instructed to use computers in multiple locations in the building and not to speak with each other, relying solely on the instant messaging system included with the spreadsheet to communicate. The chat traffic was consistent with individuals unable to otherwise communicate. The instructor was also logged in as a user and recorded portions of the solution process. A screen capture of the sheet in progress is presented as Figure 1. The sophomores spent about an hour on the problem.

The seniors in the engineering economy course were expected to develop a spreadsheet to enable a user to compare the total costs of living for purchasing a home and for renting a home. No template was used for this assignment. Following a brief explanation of the project requirements as given on the assignment sheet, students were left to discuss their plan briefly before heading to computers in different locations as before. Chat traffic was again consistent with a group of students not able to speak with one another. A recording was also made of their solution process, although it was more complicated because this class (appropriately) used multiple sheets in the workbook to isolate inputs and outputs from computations. A screen capture of the student's efforts near completion is given in Figure 2. The seniors spent about 45 minutes completing the project.

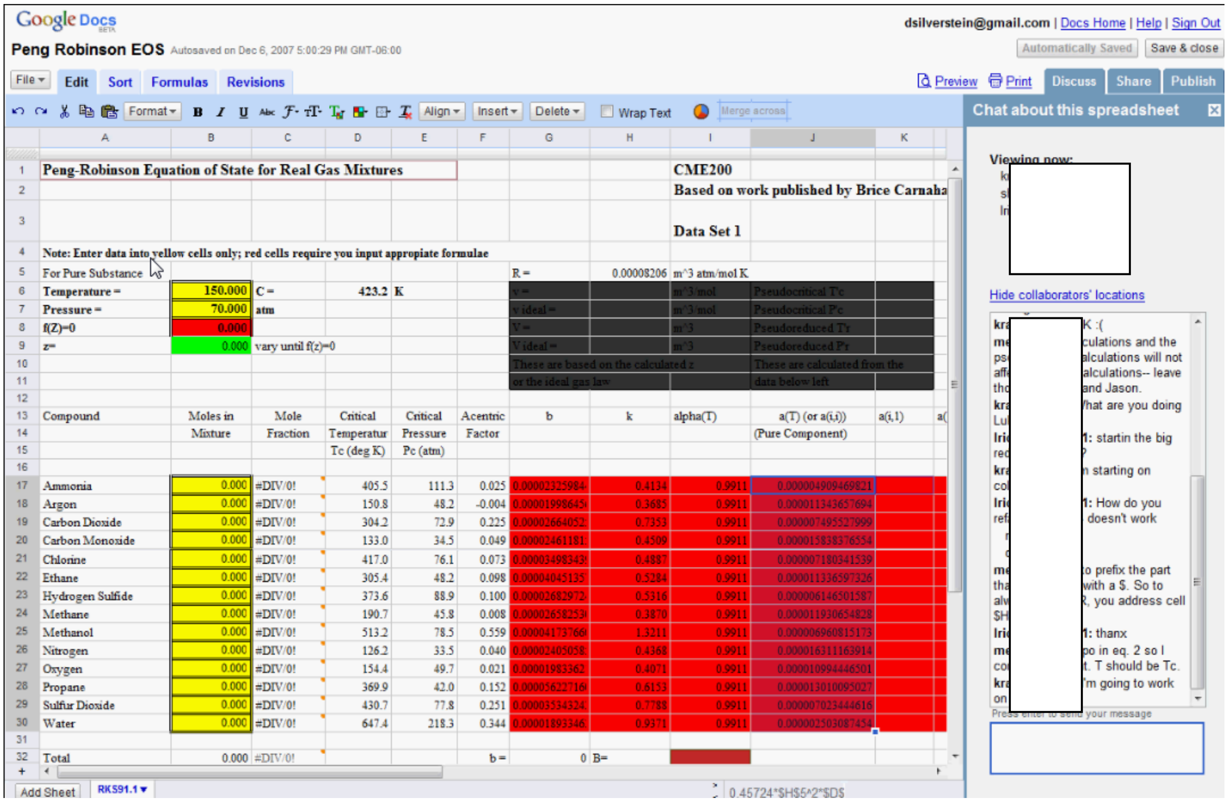

Figure 1. Peng-Robinson equation of state problem given to sophomores, based on work by Bryce Carnahan. Names of particpants have been obscured.

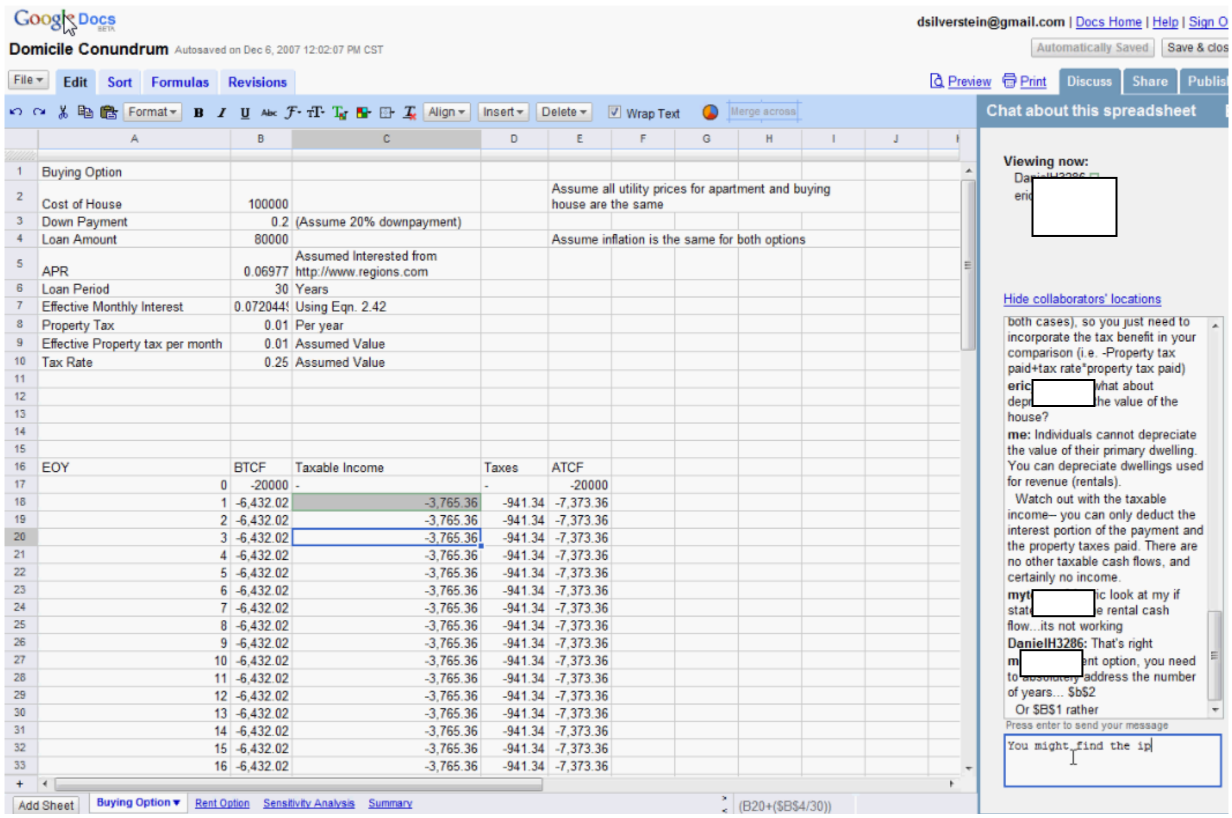

Figure 2. Seniors completing their rent vs. own comparison spreadsheet. Names of participants have been obscured.

Results and Discussion

In both cases, students were able to complete the solutions of their problems on a timely basis. Suggestions were infrequently offered by the instructor via instant messaging to limit the time spent on this project.

All surveys asked students to respond to questions and answer them using a 5-point Likert scale (1=Strongly Disagree, 5= Strongly Agree). Sample size for sophomores was 5 on the pre-assessment and 4 on the post-assessment. For the seniors, the sample size was 3 on both assessments. Standard deviations are not given due to the small sample size.

The first group of questions that students were asked were used to establish the prior experience of the students as presented in Table 1. Students indicated they had not previously used Google spreadsheets, but almost all had experience with instant messaging. More advanced students were far more likely to have had teamwork training, which is a component of our curriculum.

	Sophomores	Seniors	Combined
Used Google spreadsheets previously	1.0	1.7	1.25
Used instant messaging previously	3.0	5.0	3.75
Had prior teamwork training	2.8	4.7	3.5

Table 1. Results from questions regarding prior experience asked prior to the project.

Students were satisfied with the capabilities of the online spreadsheet, though some were uncomfortable with the lack of familiar features which might have been useful for the assigned problems. Table 2 shows the results from relevant questions. In particular, the sophomore class problem would have been solved more elegantly with a goal-seek function. Perceptions changed notably before and after using the spreadsheet. Perhaps the most interesting result was that students indicated they were not as likely to use the online spreadsheet for an individual assignment was they were for a team project.

	Sophomores		Seniors		Combined	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
Google spreadsheets (GS) are as easy to use as Excel	1.8	4.3	3.0	2.7	2.3	3.6
GS contain all the functionality I need for engineering problems	1.8	3.0	3.0	4.0	2.3	3.4
We never lost data when developing the spreadsheet		4.5		4.3		4.4
I would use GS for suitable individual problems		2.5		3.0		2.7
I would use GS for suitable team problems		4.8		4.0		4.4

Table 2. Results from questions associated with the usability of Google spreadsheets.

Teamwork was the final topic addressed by student surveys as presented in Table 3. Sophomore students appeared to develop a greater appreciation for the value of planning and organization in team projects, while seniors indicated no change in their perceptions. The spreadsheet itself seemed to facilitate communication amongst team members adequately, both through an effective instant messaging applet and through adequate indication of where other team members were working within the spreadsheet. The collaborative features of the spreadsheets were perceived to have required less time to solve the problem compared to other collaborative methods.

	Sophomores		Seniors		Combined	
	Pre-	Post-	Pre-	Post-	Pre-	Post-
We have planned how to execute this task	1.6		2.7			2.0
We have/had determined how to solve the problem prior to beginning calculation	1.6	3.0	2.7	3.3	2.0	3.1
We planned sufficiently to execute the assigned task		4.5		2.7		3.7
Planning is more important when working on a project simultaneously	2.8	4.8	4.7	4.3	3.5	4.6
It was less time-consuming to work simultaneously on the same spreadsheet		4.5		4.0		4.3
Instant messaging was an effective means of communication		4.5		4.3		4.4
I coud tell what my team members were doing		4.5		4.0		4.3
I worked more than I would have if we had gathered around a single computer		3.5		2.7		3.1
Teamwork instruction was important to the project's timely completion		4.3		4.0		4.1

Table 3. Teamwork assessment questions.

Students were also asked some free-answer questions regarding the spreadsheet application and the project. Students commonly indicated that the collaborative nature of the spreadsheet was appealing, with the problem being solved rapidly with everybody contributing simultaneously. Shortcomings of the spreadsheet primarily involved usability, including lack of common shortcuts (F4 for toggling absolute cell references), poor visibility of cell contents, and lack of prompts for function arguments. The best feature appeared to be the integration of the instant messaging system.

Students indicated that more time to prepare for the project would have been useful, or perhaps setting a time limit to make certain students plan ahead. More general comments included:

> "I really enjoyed it. I really like working in teams."
> "The project was very interesting due to the fact that the spreadsheet can be compiled so quickly."
> "It seemed to fly by once everything started clicking."
> "fun yet challenging"
> "interesting possibilities"
> "That was fun"
> "Best homework all semester"
> "Got to chat with each other"

All students participating received full credit for the assignment, which counted as a homework grade in each course.

The instructor noted that students had greater interest in this assignment than they have had for essentially the same assignment in previous terms. Much of this excitement can likely be attributed to the novelty of the browser-based spreadsheet. Individual contributions could be observed by the instructor, and those students with more developed spreadsheet skills completed a great proportion of the tasks required by the assignment. The spreadsheet was judged by the instructor to be sufficient for problems that do not require iterative calculations or goal-seek functions, and will likely be included in future course offerings.

There is no additional instructional overhead required for an assignment involving this collaborative spreadsheet beyond a brief introduction to Google Docs, nor is there need to monitor student activities in the manner performed for the purposes of this project. Any assignment involving use of a spreadsheet can involve use of this application, provided that the calculations are not subject to the computational limitations of the application (no iterative calculations, Goal Seek, or Solver). The application offers no additional benefit in monitoring for academic integrity, and is potentially more susceptible than Excel since Excel offers internal tracking data which can be extracted by the skilled instructor. Training requirements are the same as for Excel with minor additions for operational details specific to Google Docs.

Conclusions

This project investigated the utility of an online collaborative spreadsheet for small groups of chemical engineering students to solve problems. The software tools were judged adequate by both the students and the instructor. Despite the requirements of a browser-based online spreadsheet, it was responsive and stable on multiple classes of system running different browsers. The calculation capability is adequate for many engineering problems, but will not replace the desktop spreadsheet in the near term. The communication capabilities of the software make the spreadsheet very appealing for group projects, enabling the social element of instant messaging to group discussions. Team training enhanced the experience of collaborative problem-solving for students, and appeared to lead to a better appreciation of the importance of planning to successful group projects.

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