Assessment in Online and Blended Learning Environments

Continuous Formative Assessment (CFA) During Blended and Online Instruction using Cloud-Based Collaborative Documents

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Abstract

This chapter describes the Continuous Formative Assessment (CFA) model for utilizing cloud-based collaborative document technology to instantly collect responses from multiple students, groups, and class sections. Utilizing CFA, instructors can collect student response data from large sets of students across groups or classes and analyze them quickly and accurately. Instructors of online and blended learning courses can employ CFA strategies to enhance student engagement and monitor student understanding during synchronous online or in-

person instruction. As instructors analyze student responses, instruction adjustments can be made to meet immediate student needs. This chapter introduces specific instructional strategies that may be employed to increase the accountability and involvement of students in online settings. Preliminary data suggests that the CFA methodology promotes engagement, accountability, and understanding through formative assessment for both students and instructors.

Introduction

Blended and online learning environments provide instructors with significant challenges regarding the engagement and assessment of learners. How can teachers engage learners and assess their understanding in remote settings? Furthermore, how can instructors perform formative assessment to adjust their instruction to meet the immediate needs of distant learners? The Continuous Formative Assessment (CFA) model helps teachers create an environment that engages learners and provides opportunities for instructors to monitor student progress through continuous formative assessments so they can modify instruction to maximize learning in blended and online environments.

Schools and universities have been encouraged to develop a "culture of assessment" to provide evidence on the effectiveness of instructional programs (Weiner, 2009). Although the emphasis on assessment has produced a wealth of literature, legislation, initiatives, reforms, and professional development, the vast majority has focused on assessment ***of*** learning (summative assessment) rather than assessment ***for*** learning (formative assessment). Formative assessment is generally defined as a process used by teachers that provides feedback by which they can adjust ongoing teaching and learning to improve achievement during the process of instruction (Popham, 2008). What makes formative assessment 'formative' is that it is immediately used to make adjustments to instruction to meet the needs of the learners during the construction of understanding (Shepard, 2005).

Formative assessment is not a new concept, and any teacher who adjusts his or her teaching during instruction on the basis of evidence of student understanding and performance is employing formative assessment (Popham, 2008; Shepard, 2005). Traditional formative assessment techniques such as student questioning or quizzes are limited in how many students are assessed or can be difficult to analyze during class. The challenge is even greater in online environments were there is limited interaction with students. How does one accurately assess student comprehension and performance during a class session, particularly in blended and online settings?

A promising response to this question is found in new collaborative cloud-based document technologies. Such technologies provide the opportunity to instantly collect and analyze large sets of data from multiple students, groups and class sections with speed and accuracy, regardless of the physical location of students. The CFA instructional model employs these technologies to create environments that mirror collaborative professional research communities in which colleagues evaluate each other's work and ideas on a continual basis. Similarly, teachers create blended and online classroom activities in which students analyze whole-class data using collaborative cloud-based spreadsheets, documents, wikis and presentations. These activities help students gain an understanding that the learning enterprise requires collaboration, independent verification, and peer review. This chapter will introduce a range of collaborative cloud-based activities through which educators can continuously monitor student ideas and adjust their instructional practice to enhance student learning.

Literature Review / Conceptual Framing

To understand *formative assessment* and its role in online and blended instruction, it is helpful to contrast it with *summative* and *interim assessments*. *Summative assessments* are generally "high-stakes" tests that are used to determine student grades and class-wide or school-wide performance. Summative assessments are used to measure mastery of predetermined content or standards and are the backbone of accountability systems at all academic levels. Student grades, college admission, scholarships, graduation, and school rankings are all determined primarily by summative assessments. Summative assessments play a critical role in accountability systems and inform local, statewide, and national educational policies (Perie, Gong, & Wurtzel, 2007).

Although summative assessments are invaluable for accountability, they cannot be used to diagnose gaps between student knowledge and the intended curriculum at a time when instructional adjustments can be made to benefit student learning. Summative assessments inform stakeholders concerning what students did or did not learn, but do not provide information that will change instruction to benefit current students. Educators therefore employ *interim assessments* throughout instruction to provide such information. Interim assessments, also known as medium cycle assessments, are administered throughout a course to provide information to diagnose problems and provide information on how instruction can be changed to best meet student needs. Interim assessments take many forms, such as quizzes and reports, and may factor into final grades and school or system assessments. Interim assessments provide students with practice for summative tests and provide teachers with information necessary to adjust future instruction (Perie et al., 2007; Pinchok & Brandt, 2009).

Although summative and interim assessments provide invaluable information and help establish an environment of accountability, they do not provide instructors or students with the information necessary to improve teaching and learning during the actual instruction. By contrast, *formative assessments* are embedded in instruction and are directly linked to teaching and learning *as it occurs*. Formative assessments identify gaps in understanding and can be used by teachers and students to make adjustments to improve student learning *as it occurs*. Formative assessments can be frequent and provide teachers and students with timely feedback on progress (Black & Wiliam, 1998; Black & Wiliam, 2009; Shepard, 2005).

There is much research to show that formative assessments can be used to improve student learning success. Meta-studies analyzing the findings of numerous investigators concluded that formative assessments provide "moments of contingency" (Black & Wiliam, 2009, p. 10), critical points where learning changes direction depending on an assessment. Well-designed formative assessments provide information to make instructional modifications in real-time to address student needs (Black & Wiliam, 2009; Shepard, 2005). There are numerous techniques that can be used for formative assessment including hand raising (in response to specific questions), hand signals (to measure levels of self-reported understanding), choral responses (in which students are invited to respond simultaneously to teacher-posed questions), think-pair-share (in which teachers assess student understanding as student groups share with the class), quick-writes (in which students make journal entries in response to specific prompts), exit cards (in which students submit questions or answers as they leave class), self-assessments (in which students check their own understanding by working problems or answering questions in class) and quizzes (in which teachers pose questions to test student understanding) (Bernackic, Ducettee, Majerichb, Stulla, Varnumd, 2011; Fluckiger, Vigil, Pasco, & Danielson, 2010; Jahan, Shaikh, Norrish, Siddqi, & Qasim, 2013; Youssef, 2012). All of these techniques have proven valuable in traditional classroom settings but many of these still do not provide the instructor with an immediate assessment of student needs.
For example, the instructor gathers cards and reads them after class or grades quizzes after class.

Formative assessments have been shown to be particularly valuable with lower performing students. Learning deficiencies can be identified early in the learning cycle, allowing instructors to make teaching modifications before lower performing students are left behind (Athanases & Achinstein, 2003). Numerous textbook publishers produce online quizzes to provide students and instructors immediate feedback, and such products can be very effective in helping identify gaps in students' understanding (Hoon, Chong & Ginti Ngah, 2010). Formative assessment is an iterative "joint productive activity" in which students assemble and interpret knowledge and present their understanding to their teachers who then adjust instruction to optimize learning. This process is repeated throughout learning units (Ash & Levitt, 2003).

Bandura (1997) and Zimmerman (2002) suggested that formative assessments permit students to express themselves and develop a sense of self-efficacy, a key requirement for the development of autonomous learning strategies. Polanyi (1967) and Schön (1987) emphasized the formative and reflective purpose of student discourse and encourage an open community of learners where ideas and opinions are exchanged so that students can co-construct their understanding. The CFA model provides an environment where such discourse can take place, but unlike traditional instruction where certain students dominate and others are passive, all students are on an equal footing since all have access to the same document for their contributions. A discussion of the underlying theories on which the CFA model is built as well as practical instruction for implementation and findings from ongoing research follows.

Formative Assessment and Technology

Online education has grown dramatically in recent years and is expected to continue growing in the years to come. In his State of the Union address, President Obama suggested that technology will play an increasingly significant role in America's plan to increase the number college graduates while decreasing the cost of education (Obama, 2010). The President encouraged the growth of online education to attract more students to college, particularly those from populations under-represented on traditional brick-and-mortar campuses (Sturgis, 2012). The growth of online and blended education has been accompanied by a growing concern regarding the quality of online education (Hirner & Kochtanek, 2012). Although it is easy to see how formative and interim assessments can be used to measure student understanding in online and blended classes, it is more difficult to see how formative assessments may be employed to directly inform instructional strategies and pacing.

The first electronic solution to formative assessment was the audience response system developed in the early 1970s (Simmons, 1988). William Simmons, an executive at IBM, reflected on the lack of productivity in corporate meetings. Only one person could talk at a time and each decision required a formal vote. Executives often did not speak their mind because of the desire for conformity with the opinions of their superiors. Simmons worked with Theodore Gordon of the Futures Group to design and develop an electronic audience response system. Simmons applied this technology in corporate meetings and found he got not only greater engagement but also more honest feedback. Simmons found that he could instantly get information on the group's true consensus (Simmons, 1988).

Today there are many audience response systems, also called "student" or "classroom" response systems, in use in educational settings including dedicated "clickers", computer software, and smart phone apps that aggregate student inputs (Kay & LeSage, 2009). Such systems track individual responses, display polling results, confirm understanding of key points, and gather data for reporting and analysis. These hand-held dedicated systems allow students to input responses to questions posed by their instructor. The instructor receives immediate statistics on student performance on true-false, multiple-choice and short-answer questions. Studies have shown improved student participation, attendance, and learning with the use of student response systems (Beatty & Gerace, 2009; Bennett & Cunningham, 2009; Buchanan, 2001; Chevalier, 2013; Gok, 2011; Peat & Franklin, 2002). Such systems not only provide information for teachers, they increase accountability for students (Kaleta, 2007). Although student response systems have been shown to be a valuable formative assessment tool, current systems do not provide adequate means for free response questions. They have limited input capabilities and cannot receive complex text, audio, video, or graphic responses that can be used to assess higher levels of understanding. Some uses also require assessments to be prepared in advance, limiting the ability of the teacher to make a spontaneous assessment.

Most student response systems require instructors to create multiple choice and short answer questions prior to class. Although such systems have the advantage of providing detailed and immediate statistics on student understanding, they fail to give any insight into the thinking of the student and the reason for their understanding. To circumvent the limitations of hand-held student response systems, researchers at Colorado School of Mines (CSM) developed free web-based software known as *InkSurvey* that enables students to use pen-based mobile technologies to respond to the open-format questions of their instructor with diagrams, equations, graphs and proofs (Kowalski, 2013a). The instructor instantly receives student responses and thereby gains real-time insight into student thinking and can immediately reinforce correct understandings and address misconceptions as they develop. *InkSurvey* has been used successfully in college physics and engineering classes with enrollments exceeding 60 students. Researchers determined that when interactive engineering computer simulations were coupled with real-time formative assessment data collected with *InkSurvey*, students achieved large and statistically significant learning gains regardless of their learning styles (Kowalski, 2013a).

The formative assessment techniques mentioned so far have been shown to be effective in traditional face-to-face classrooms, but can they be used in synchronous or asynchronous online or blended classes? Indeed, many of the techniques mentioned so far can be replicated using cloud-based collaborative resources. Reviews of the literature show that interactive online formative assessments can foster a learner-centered focus and enhanced learner engagement (Gikandi, 2011). Online feedback systems that are integrated into the student's online learning space have been shown to improve student engagement and performance (Chen 2009; Hatziapostolou, 2010; van Gog 2010). Interactive computer-marked assignments and conventional tutor-marked assignments have been shown to help students keep up-to-date in their studies (Jordan, 2009). Others have experimented with social networking to promote peer-to-peer collaboration and formative assessment (Blue & Tirotta, 2011) and some have shown that blogs can be used as a student-based formative assessment tool to cultivate reflective peer-to-peer learning (Olofsson, Lindberg, Hauge & Trond, 2011). Others have shown that anonymous electronic feedback systems can be beneficial in stimulating instructors to make changes to improve the delivery of online courses (Berridge, Penny & Wells, 2012). Collectively, such studies have indicated that web-based formative feedback can be instrumental in improving the student learning experience.

The need for new formative assessment methods

As mentioned previously, schools and universities are encouraged to develop a "culture of assessment" to provide evidence on the effectiveness of instructional programs (Weiner, 2009). Summative assessments provide information after the fact. They tell you what students did or did not master, but they do not provide the information necessary to make changes in instructional or learning strategies while learning is occurring. Although summative assessments may provide powerful incentives for student learning, they do not inform teaching while it is occurring and therefore do not allow instructors and students to alter their approaches to optimize the learning environment. Many teachers agree that formative assessment is very important, but traditional techniques provide incomplete pictures of student understanding. For example, a "show of hands" only tells the instructor the percentage of students who think they understand, and not the percentage that truly understand nor the level of their understanding. Though many of the existing technological solutions work well for pre-planned assessment, they do not fluidly allow instructors to create follow-up prompts in real-time that modify their instruction in response to student needs.

Educators have grappled with this problem for many years and have adopted a variety of techniques in an attempt to perform continuous formative assessments. For example, in the "modeling method" of physics instruction student teams summarize their models and evidence on a small whiteboard that is easily displayed to the entire class. The whiteboard serves as a focus for the team's report and ensuing class discussions. (Hestenes, 2010; Wells, Hestenes & Swachkhamer, 1995). While this approach has been used effectively it does not produce a lasting record of student's thinking that can be referred to later. Students' work disappears as soon as the whiteboard is erased. One solution is to have students put their response on paper to be turned in as in a quick write (Clidas, 2010; Rief, 2002) or in a notebook/journal that students maintain during the course (Roberson, 2010).Both of these produce a lasting record, but the logistical challenges of assessing and maintaining them make it difficult for teachers to use them effectively (Ruiz-Primo, Li, Ayala & Shavelson, 2004).

As we move to blended learning and synchronous online learning, which combines computer-mediated activities with traditional face-to-face classroom methods, we need to think of new ways to use the best of current assessment tools. These environments create a number of new possibilities for formative assessment that allow teachers to quickly see meaningful student responses and adjust teaching based on their needs. There is a need for techniques which provide continuous formative assessment that can be used in traditional, blended and online learning contexts.

Continuous Formative Assessment (CFA)

The authors have developed a teaching technique that employs synchronous collaborative web-based documents to perform continuous, real-time formative assessments of students' understanding so that educators can adjust their instruction to address the immediate needs of their students regardless of whether they are in traditional or online settings. The CFA model has the potential to engage *all* learners *all* of the time as they provide feedback, data, quick-writes and analyses in response to instructor prompts. Using this model, teachers have the opportunity to observe all student contributions as they are made.

The CFA model has been made possible by the development of free collaborative web-based spreadsheets, documents, presentations, and drawings (Herr, Foley, Rivas, d'Alessio, Vandergon, Simla, Nguyen-Graff & Postma, 2012a,b; Herr & Rivas, 2010; Herr, Rivas, Foley, Vandergon & Simila, 2011a,b; Rivas & Herr, 2010). Online tools like Google Documents or Windows Office Live allow teachers to develop online documents and share editing privileges with their students. The shared documents provide a platform for formative assessment as both the teacher and the student have immediate access to the documents. For example, in a blended classroom in which students have computers or tablets, or in an online synchronous lesson, teachers can use a shared online spreadsheet to record students responses. Teachers enter student names in column one and pose a question in the header of column two (Figure 1). Students respond to the question in the cell next to their name, providing the teacher with instant information regarding current student understanding of the lesson. This process can be repeated throughout the class allowing teachers to assess their students continuously. The spreadsheet becomes a lasting artifact of student thinking and can be analyzed later or referred to by both the teacher and the students.

Although many companies now offer online documents, Google offers the most comprehensive suite of free resources, and so we shall discuss their offerings in more detail. In 2006 Google acquired Upstartle, the software company which introduced the first web-based word processor. In addition, Google acquired rights to the first web-based spreadsheet from 2Web Technologies (Google Press Center, 2006). In 2007, Google developed the first web-based presentation program (Bodis, 2007) and introduced all three as a free development suite known as Google Drive®. Any individual who opens a free Google account has an automatic link to Google Drive ® (formerly called Google Docs®). Users can develop documents, spreadsheets and presentations online using any modern browser, or can import them from a wide range of formats. Google documents are automatically saved to Google servers whose actual location or name is not needed. These documents are described as being located "in the cloud." As with related wiki technologies, a revision history is associated with each document so users can review, revise and/or reverse editorial changes.

Cloud-based documents allow for the type of collaboration and sharing environment for productive student learning communities (Falkner & Falkner, 2012). Teachers and students can work on the same file as they co-author reports, creative writing and other document. As students collaborate, each can see which revisions have been made by their colleagues, and can reverse or restore changes by selecting options in the revision history. Rather than working on original files and sending copies for peers to work on, all students work directly on the original so there is no confusion about the current status of the document. Such web-based development resources preclude the need for expensive software, since all one needs is a free downloadable web browser.

Collaborative cloud-based document technology creates new opportunities for formative assessment involving laboratory science experiences. While ideal science laboratory experiences should help *develop scientific reasoning* and an *understanding of the complexity and ambiguity of empirical work* (National Research Council, 2006), many laboratory experiences that students receive do not assist in the achievement of these goals. Web-based documents can provide an opportunity for students to understand the complex and collaborative nature of empirical research as they collect and analyze data from multiple lab groups, classes, or schools (Herr et al., 2011a; Herr & Rivas, 2010). Data collection can be simplified by survey tools, such as Google Forms®, that link directly to online Google Spreadsheets®. Teachers or students can develop forms online and then invite students to input their findings. Spreadsheets are created from the data, with records (rows) representing the lab groups, and fields (columns) representing answers to specific questions. Links to survey forms and their associated spreadsheets can be provided by copying document addresses to email messages, blogs, newsgroups or websites. Students reply to the online forms, and together build a single spreadsheet file that is shared by all.

Within moments, an entire class can input their data, generating a table with as many records as there are laboratory groups, and as many fields as there are questions on the form. These data sets can be analyzed with built-in online tools and "mashup gadgets" (web application hybrids), or downloaded to each group for analysis with traditional tools such as Microsoft Excel®. The instructor can easily analyze all contributions on a single screen, regardless of the physical location of the contributors. This provides the opportunity for formative feedback and possibly peer feedback as the results are apparent to all. For example, an online instructor can collect observational weather data from their students and then analyze it in light of weather station reports of temperature, pressure and dew point. As class is conducted in a medium such as Google Hangouts (a free video conferencing) or Collaborate (Blackboard's tool for synchronous online instruction), both the instructor and all of the students can continuously monitor all student data which is plotted on a Google Spreadsheet. This monitoring allows a new level of formative assessment for data collection, as many errors can be identified and corrected before it's too late (d'Alessio & Lundquist, *in press*).

Many classroom experiments call for the measurement or calculation of specific values, such as the density of water, the molar volume of a gas, the wavelength of a laser's light, or the percentage of root tip cells in mitosis. Students may notice that their values differ from those of other lab teams and thereby gain an understanding of the value of descriptive statistical measures, such as mean and standard deviation, when analyzing experimental data. As students graph class data using web-based spreadsheet tools, they may note bell-shaped distributions and gain a more intuitive understanding of the normal curve and basic descriptive statistics. Bimodal distributions may indicate the use of two different techniques while random distributions may indicate flaws in experimental design or implementation. By analyzing class data sets, students learn the complexity of the natural world and see the need for standardizing procedures and controlling for confounding variables. Thus, collaborative web-based technologies can be employed to provide continuous formative assessment of laboratory techniques (Herr et al., 2010a; Herr et al., 2010b). Many science educators shy away from online and blended learning environments because they believe that such environments do not provide realistic laboratory experiences and lack the community that is so important to scientific research. The CFA model can address many such concerns by bringing students together online to conduct collaborative investigations.

Web-based documents can be employed to help students learn aspects of the nature of science and gain experience working in large teams. Scientists work in research laboratories that are part of larger networks and associations, and share their findings with their peers through journals and conferences. In the traditional college or school science classroom, only the instructor reviews student work. Web-based document technology provides students the opportunity to work cooperatively in the collection of data, analysis and assessment of peer data.

Web-based document technologies (e.g. Google Documents, Spreadsheets, Forms, and Presentations®) provide an environment for collaboration, but online instructors must develop appropriate activities and lessons if they plan to capitalize on the opportunities the technology affords. For example, an investigation may ask students to find the relationship between mass, length, and the period of a pendulum. Students in an online or blended physics class can submit the results from experiments performed at home to a collaborative form or spreadsheet. Relationships that are invisible with the few data points collected by a single lab group become clear with the addition of whole class data. If each group measures the period of a pendulum using different weights and lengths, then students will have large data sets to analyze. Using *spreadsheet curve-fitting* technology, students can find the equations that best fit the class data. By analyzing whole class data, students can determine that the period of a pendulum is independent of mass, but directly dependent upon the square root of the length of the pendulum. Such conclusions can be made quickly when working with whole class data, but may take a long time if each lab group must independently generate all of the necessary data. Pooled data makes it easier to find mistakes and correct them during the activity. Rather than waiting for the final lab report, teachers and students can assess data as it is input into the cloud-based spreadsheet where mistakes will often show up as outlying points. By performing a formative assessment on student data immediately upon input, the instructor can save students much wasted time trying to interpret flawed data.

Techniques for Continuous Formative Assessment

All of the following techniques use collaborative online resources. In each case, the instructor sets up a document on which students simultaneously enter data, or a folder to which students simultaneously upload documents. The instructor establishes sharing privileges so that students can access these resources using their email login and passwords. By making such resources private, the instructor can identify the contributions made by each student. In addition, the instructor can analyze the revision history to see a chronology of changes made by specific students. The following techniques are possible with both computers and mobile communication devices such as phones and tablets.

CFA Technique 1- Online Quick-write - The electronic quick-write is perhaps the most useful of all of the CFA techniques. The instructor sets up a spreadsheet such that student initials, names or ID numbers are in column 1. He or she then starts asking questions and provides a brief title at the top of the adjacent column. The instructor can tell when students start to type because their cells turn gray. Once they press the enter key, their entry appears in the appropriate column. Figure 1 shows the first few rows and columns of a quick-write that was made for a particular class. The first column shows that all but one of the students (row 14) know the mathematical definition of pressure. The instructor then asked the students to complete the sentence, pressure is…. In this open ended environment, students produced a variety of responses (column C) which indicated that they did not truly understand the formula which they had just accurately written.

	A	B	C	D	E	F
1	**Initials**	**Pressure equation**	**Pressure is...**	**predictions of the candle / flask**	**how do you collapse a tank car?**	**How high?**
2	**CV**	P=F/A	force	the flame will go out	heat water inside, let it evaporate, then seal off tank	10m
3	**DF**	f/a	weight weighing down on you	flame will go out	heat water inside	10m
4	**SA**	p=f/a	gravity	water turn to vapor, then flame go out if avaliable oxygen is burned/used up	water inside and heated tank with cold surroundings	10m
5	**GG**	p=f/a	force over a specific area	some liquid will rise and candle will go out	lower pressure inside. heat water inside and let it evaporate into vapor, seal	10m
6	**HE**	P =force of a unit volume	force	flame will go out,water level will increase on the outside, level on inside will be less	change in temperatrure closed to open container	10 m
7	**NG**	P = F/A	Force pushed onto lower pressure to raise to high pressure	pressure inside drops as steam condenses - Outside pressure pushes water up	Have water inside tank, heat, seal the hose attached to tank with cooler temperature water	32 m
8	**HH**	p=f/a	pressure is a force	the water is going to go up a little into the flask and put the flame out	heat up water inside and then seal the tank	10 m
9	**JK**	p=f/a	the force on an object	candle will create steam, the water will rise and put out the candle	heated water inside of the tank, then sealed and cooled the tank	10m
10	**LO**	p=f/a	ratio of force distribution	the water will rise and put out the fire	put water inside and then heat it up and seal it	100 m
11	**TY**	force on a given area	force on a given area	candle flame goes out, gas pushes water level up	heated water in open tank then seal	10m
12	**SS**	force per area	a force	the water level should rise in the flask.	same way as the can	10 m
13	**SR**	p=f/a	force on something	candle will go out	lower pressure inside the tank, higher pressure outside	10m
14	**FR**	P=F	pressure is a force	The heat from the candle will make it buoyant/ flame goes out	evaporate a small amt of water then seal the tank	10m
15	**DW**	P=F/A	force per unit area	Flask will get smoky, then flame will go out, then water will rise	Fill with steam, seal and wait	10 meters

Figure 1. Example of an electronic quick-write in which a teacher asks students to respond to prompts which are typed in the top row of a spreadsheet. Each student uses the row with their initials.

By examining the data in columns B and C, the instructor is able to do a quick formative assessment regarding students' understanding of pressure. Namely, students seem to "know" the formula for pressure, but do not know how to express the formula in words. Being able to ask open-ended questions enables more complex questions requiring students to demonstrate understanding. This provides a "moment of contingency" at which the instructor needs to illustrate how to turn algebraic equations into sentences and thus help students understand the meaning of this and future equations. Without this formative assessment tool, it is quite possible that the instructor could continue teaching, assuming that students truly understood the concept of pressure.

In column D students are asked to make a prediction regarding what will happen when a flask is inverted on top of a burning candle that is standing in a tray of water. This question was asked as a follow-up to a similar activity where students observed soda cans spontaneously collapsing under atmospheric pressure when steam inside the empty cans condensed. A quick survey of column D shows the instructor that only one student (row 7) seems to make the connection between the two phenomena. The instructor is then prompted to show a video of a railroad tank car that collapses under normal atmospheric pressure. In column E we see that nearly everyone is making a correct prediction, which is most simply described in row 15. Finally, the instructor assesses his or her students' knowledge of atmospheric pressure by asking a question in which they must determine the height to which air pressure can push a column of water in an evacuated tube. At this point, the instructor sees only two errors (rows 7 and 10) and decides that it is appropriate to move to the next level of understanding regarding pressure.

With CFA, instructors open a single spreadsheet document and simply add multiple worksheets to it. If each worksheet is dated, the instructor has a comprehensive picture of student understanding for each day of instruction. Eventually students stop raising their hands to answer questions, and automatically enter their responses in the spreadsheet. The instructor can quickly scan the spreadsheet for blanks. Any blank indicates that the student was either off task or unable to answer the prompt. In a normal classroom, students often defer to the "good students" who offer verbal responses. The instructor gets only one data point to go on, and it is generally data from one of the best students in the class who is willing to raise his or her hand in order to contribute.

The online quick-write provides instructors the opportunity to get student responses on many questions in a single period. This technique works very well in online environments and provides the instructor with immediate data regarding the engagement and understanding of all participants, regardless of their physical location.

CFA Technique 2 – Collaborative Presentation – Instructors can assess student understanding by assigning each an individual page in an online presentation and watching the presentation develop in response to a teacher prompt. Figure 2 shows a presentation that was made when trying to illustrate the concept of order of magnitude in measurements. Students were assigned an order of magnitude and were to find a photo of an object at that scale. The collaborative presentation differs from the collaborative spreadsheet in that each student is assigned a unique page rather than a unique row in a spreadsheet. These pages can accommodate not only text responses, but also audio and video files.

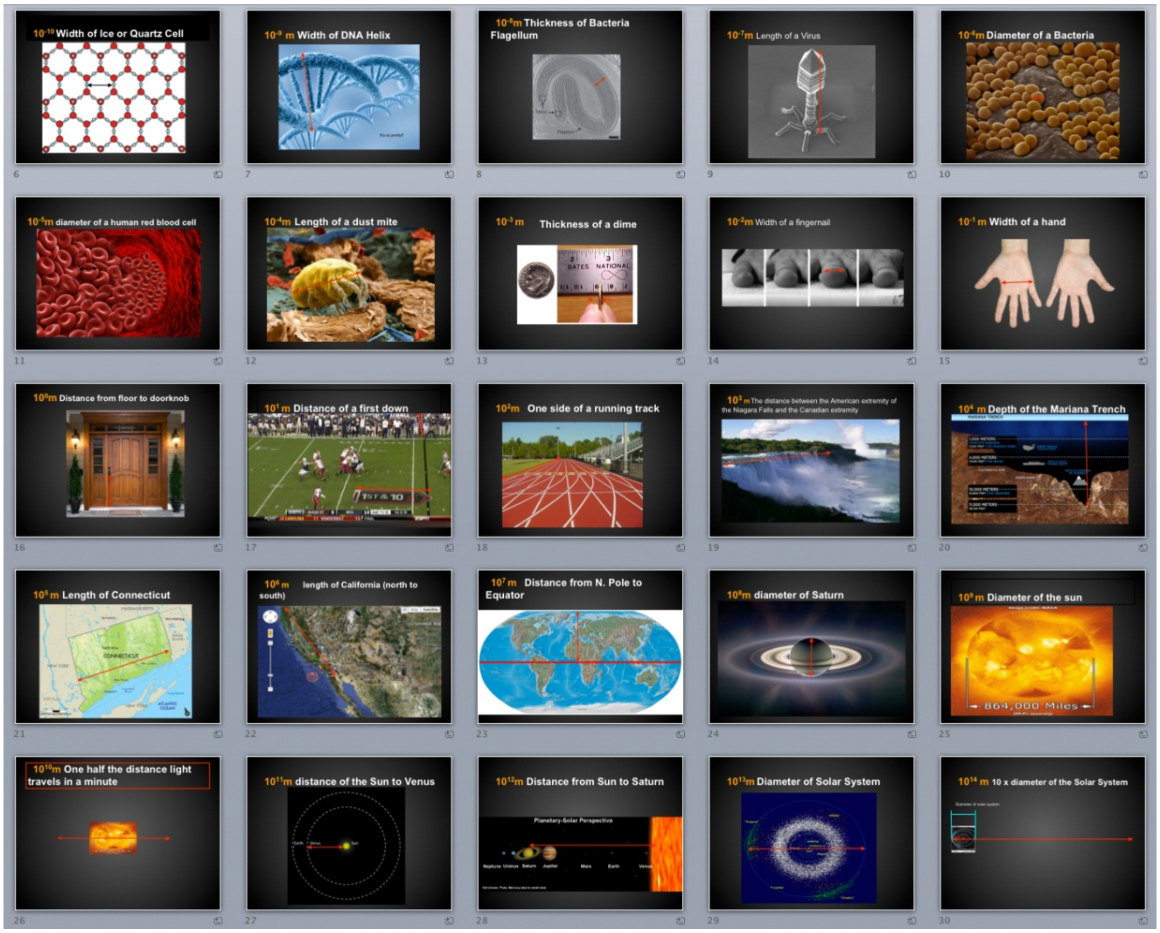


Figure 2. Slides from a collaborative presentation. Each student added one slide to illustrate an order of magnitude of size.

CFA Technique 3 – Collaborative Diagram Album – Teachers often ask students to diagram the subjects being discussed in class. The whiteboard methods used by Hestenes (2010) and others provide a way of quickly sharing student-generated diagrams. To see students work in an online or blended setting, the teacher can ask students to use smart phones to scan their drawings and upload them to the class folder in the cloud In Figure 3, students were asked to draw an apparatus for measuring the wavelength of a laser beam. After each student completed their drawing on paper, they scanned it and entered it into to the shared folder. When the instructor clicks on the folder, he or she can review the contributions of all students simultaneously, and can bring student work up for illustration. With collaborative albums, teachers can monitor the thought processes of their students in real time. Unlike the whiteboard approach, the students' work is not erased when the next question is asked and can be used when students are spread around the world.

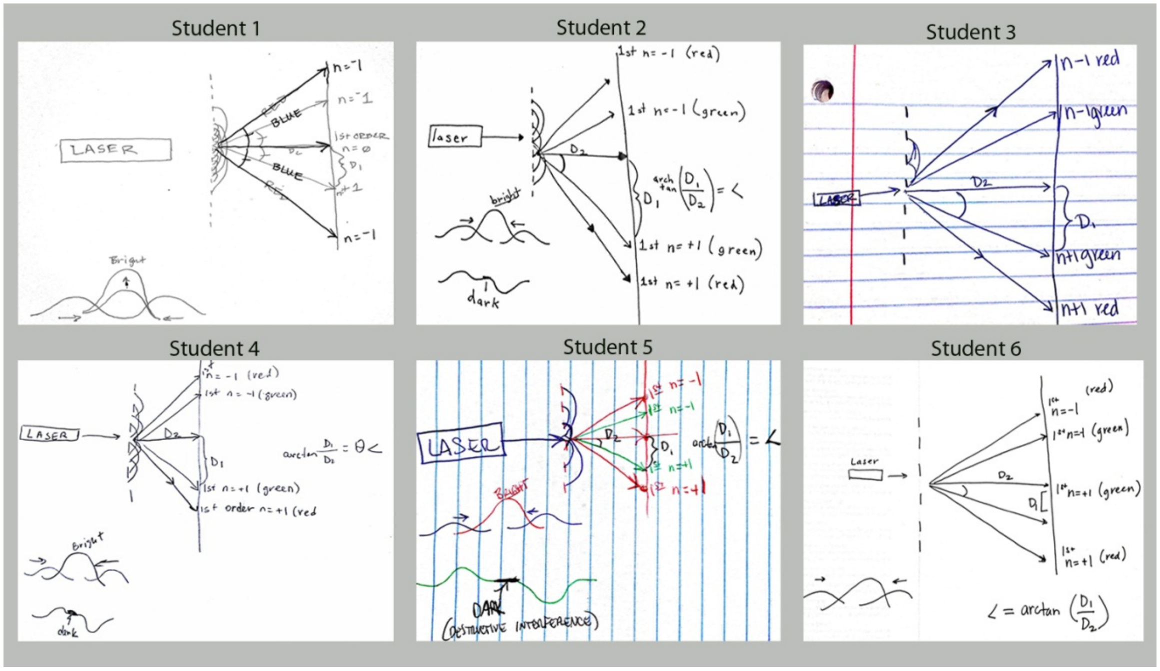


Figure 3. Student drawings collected simultaneously in a cloud-based shared folder

CFA Technique 4 – Collaborative Photo/Movie Album – As previously demonstrated, the CFA model can use any type of media, at any time, from any part of the world. In technique 3, the instructor set up a collaborative album into which students deposited scans of diagrams made with pencil or pen and paper. Sometimes, photographs or movies are more telling than diagrams or text. Using technique 4, students can take photographs or movies on their smart phone and send them to a shared folder. For example, figure 4 shows the movies made by students trying to illustrate the motions shown by the graphs. Some students made movies using their fingers, while others using the mouse, a toy car, or their entire body. Once the movies are collected, the instructor plays them back to the students in his or her online class and they evaluate their accuracy using an online quick-write. In addition to harvesting movie data, the instructor can also get photographs from his or her students. Figure 5 illustrates a shared album into which students deposited a variety of photographs of science-related topics they had seen in their communities or travels. A quick glance at the thumbnails in the album allows the online instructor to do a formative assessment on their success in meeting this requirement.

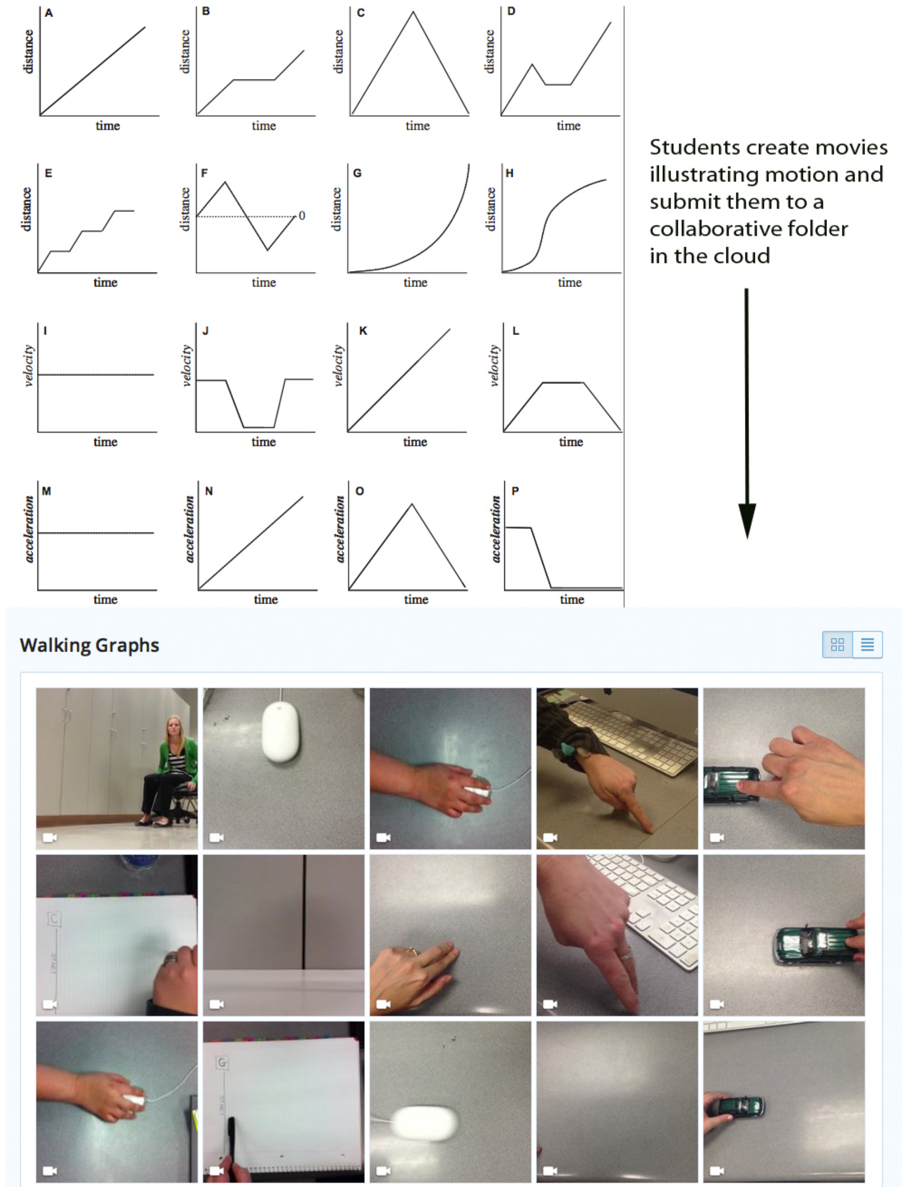


Figure 4. Collaborative movie album. Movies submitted by students to illustrate movements corresponding to graphs

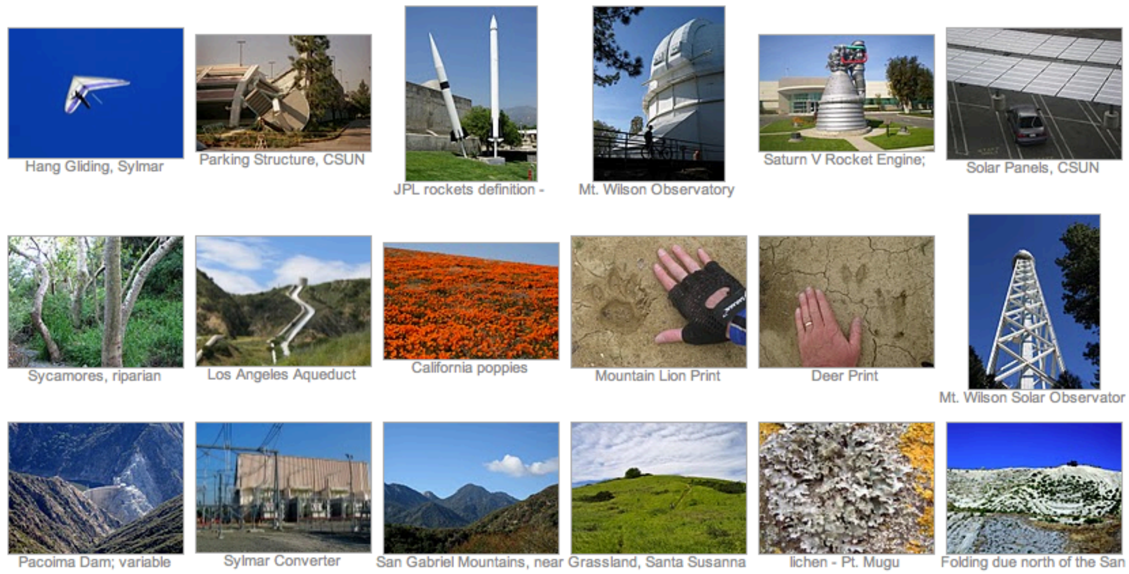
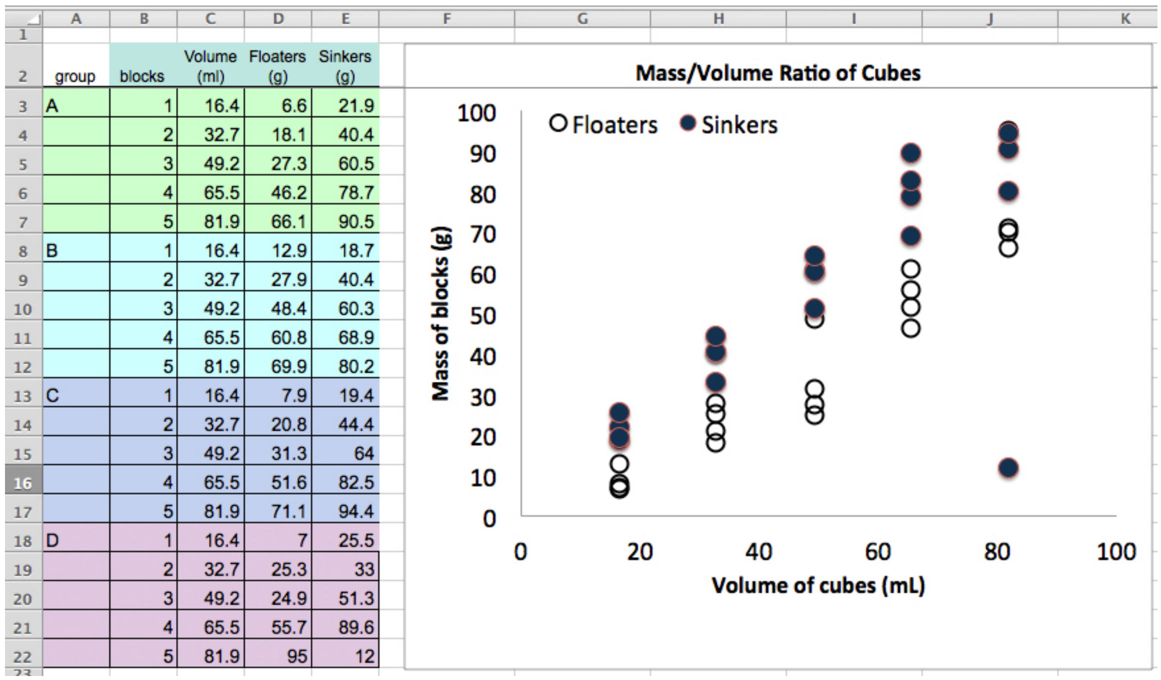


Figure 5. Online collaborative photo album. Photos students submitted to illustrate subjects of scientific interest in their community.

CFA technique 5 – Collaborative Data Plotting – One of the challenges of online learning is that it is difficult to learn from one's peers. You can't just look over their shoulder while they are doing an activity or experiment to get ideas, nor can you hang around after class to discuss techniques and strategies. Fortunately, cloud-based collaborative documents allow you to meet with your peers in cyberspace. Figure 6 shows the data collected by numerous students in a physical science class. Students were tasked with the goal of determining the factors that cause something to sink or float in water. Students assemble block combinations that vary in volume and mass and then determine if they sink or float in water. The instructor has prepared an online spreadsheet with cells for each lab group. As they enter the mass and volume of floaters or sinkers, marks are plotted on the graph. The graph develops a clear pattern when the data points of each individual or lab group are reported. Eventually, students see a clear line between sinkers and floaters and infer that anything above this line will sink in water, and anything below this line will float in water. As is intended they deduce that the mass to volume ratio of the blocks determines whether they float or sink, and the dividing line between the two objects represents the mass to volume ratio of the fluid in which they are placed. Thus, students discover the concept of density by discovery rather than by direct instruction. As students see their data plotted, they may also see some outliers and come to question the quality of such data. Outliers generally indicate something important or simply bad data. In this case, the student reversed the mass and volume measurements, and once they saw their error, they quickly corrected it. Thus, students can perform formative assessments on theevaluate quality of their own data and draw conclusions based upon their own data as well as the data of their peers.



group	blocks	Volume (ml)	Floaters (g)	Sinkers (g)
A	1	16.4	6.6	21.9
	2	32.7	18.1	40.4
	3	49.2	27.3	60.5
	4	65.5	46.2	78.7
	5	81.9	66.1	90.5
B	1	16.4	12.9	18.7
	2	32.7	27.9	40.4
	3	49.2	48.4	60.3
	4	65.5	60.8	68.9
	5	81.9	69.9	80.2
C	1	16.4	7.9	19.4
	2	32.7	20.8	44.4
	3	49.2	31.3	64
	4	65.5	51.6	82.5
	5	81.9	71.1	94.4
D	1	16.4	7	25.5
	2	32.7	25.3	33
	3	49.2	24.9	51.3
	4	65.5	55.7	89.6
	5	81.9	95	12

Figure 6. Collaborative Spreadsheet – Students submit their data to online spreadsheet an make interpretations based on pooled data.

Research Questions

The CFA model presented in this chapter raises a variety of interesting questions related to the effectiveness of formative assessment in online and blended learning environments.

(1) **Instructor Formative Assessment** - To what degree do instructors adjust their instruction to meet student needs when employing CFA compared to traditional models of instruction?
(2) **Student Formative Assessment** - What effect does the CFA model have in motivating students to applyformative self-assessments such as self-monitoring and self-correcting ?
(3) **Accountability / Engagement**– To what degree are students engaged in the instructional process by the use of CFA compared to traditional models of instruction?
(4) **Student Learning** - What effect does the CFA model have on student learning?

Methodology/Approach

To address these research questions, researchers are performing mixed-methods studies using survey instruments, observations from third-party researchers, and interviews with teachers and students. A preliminary survey was delivered online in computer equipped classrooms at the end of the Fall Semester of 2012. The participants were students in three courses at California State University, Northridge, in which CFA was employed on a daily basis throughout the semester.

Most survey questions were given in the Likert scale format. Seven of the nearly 100 questions in the survey were free response. The questions asked students to compare the effectiveness of the CFA pedagogy with other methods that they had received at the university with respect to accountability, engagement, metacognition, social learning, and intent to employ similar techniques in their own instruction. Fifty-one of seventy students completed the voluntary survey that included additional questions related to program evaluation (response rate = 73%). The students were graduates of one of the following three courses: Website Development for Teaching Science (a masters degree course for in-service science teachers), Methods of Teaching Science (a credential course for pre-service science teachers), and Computers in Instruction (a credential course for secondary school teachers, regardless of field). Twenty-one respondents were in-service teachers enrolled in a masters degree program in secondary science education, and thirty were pre-service secondary school credential students representing a variety of disciplines. Fifteen of the respondents were male, and thirty-six were female. Ethnicity demographics of the participants were not recorded in the survey.

We are currently engaged in additional research efforts to clarify the effectiveness of the CFA pedagogy in promoting effective formative assessment. Independent researchers are making observations, conducting surveys, and interviewing professors, teachers and students in university and secondary school courses in which CFA is employed.

Results/Findings

A variety of studies are currently in process to address the research questions we have proposed. We shall discuss preliminary findings, but look forward to the results of the ongoing research to provide more comprehensive answers. Students were asked to compare how accountable they felt to their instructor during instruction. They were asked to compare the course they had taken in which CFA was employed with all other courses they had taken at the university. For example, in the first question (Figure 7), students were asked to evaluate how accountable they felt to their instructor during instruction by responding to a five-point scale with values ranging from “much less accountable” to “much more accountable” compared to all other university classes they had taken. The top two values were combined to indicate respondents’ general response. Figures 7 and 8 show the results of the survey. Participants reported substantial benefits of the CFA model for the dimensions identified in our research questions:

(1) **Instructor Formative Assessment** -- Six professors at California State University Northridge (representing the departments of chemistry, geology, biology, and secondary education) have employed the CFA technique. Personal discussions with these professors indicate that all believe that CFA provides them with valuable information regarding the level of student

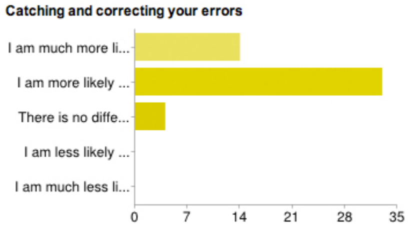
understanding, allowing them to modify lessons to maximize student engagement and learning.

(2) **Student Formative Assessment** – Seventy-four percent of respondents said that they were more mentally engaged in the instructional process as a result of the CFA approach, and 85% said that they were more likely to catch their own errors. These early results suggest that, in a class employing CFA techniques, students display an increased propensity to self-monitor and self-correct and are subsequently taking more responsibility for their own learning during instruction.

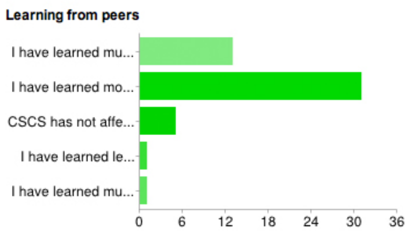
(3) **Accountability / Engagement**- The initial study showed that 77% of respondents felt more accountable to the instructor, 71% felt more accountable to peers, 75% felt more accountable for their own learning and 74% felt that they were more mentally engaged as a result of the CFA approach.

(4) Student Learning - Eighty-nine percent of respondents thought that more learning would occur if they used CFA in their own secondary school classrooms, and 96% said they intend to use the CFA model in their own instruction. This self-reported data is supported by research from colleagues at the Colorado School of Mines working with a CFA tool known as *InkSurvey* (as described above).

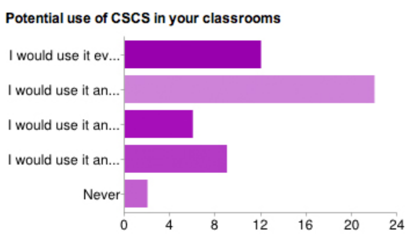
Figure 7. Survey of participants' perspectives of the effectiveness of CFA with respect to accountability and engagement in comparison with all other university courses in which CFA is not used.



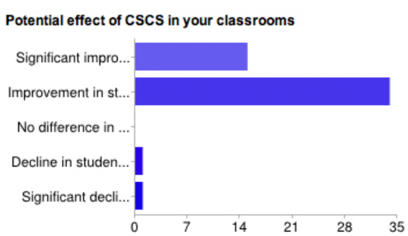
I am much more likely to catch my errors when I see data from my peers	**14**	25%
I am more likely to catch my errors when I see data from my peers	**33**	60%
There is no difference	**4**	7%
I am less likely to catch my errors when I see data from my peers	**0**	0%
I am much less likely to catch my errors when I see data from my peers	**0**	0%



I have learned much more from my peers using CSCS than if this pedagogy was not used	**13**	24%
I have learned more from my peers using CSCS than if this pedagogy was not used	**31**	56%
CSCS has not affected how much I learn from my peers	**5**	9%
I have learned less from my peers using CSCS than if this pedagogy was not used	**1**	2%
I have learned much less from my peers using CSCS than if this pedagogy was not used	**1**	2%



I would use it everyday	**12**	22%
I would use it an average of couple of times a week	**22**	40%
I would use it an average of once a week	**6**	11%
I would use it an average of once a month	**9**	16%
Never	**2**	4%



Significant improvement in student learning	**15**	27%
Improvement in student learning	**34**	62%
No difference in student learning	**0**	0%
Decline in student learning	**1**	2%
Significant decline in student learning	**1**	2%

Figure 8. Survey of participants' perspectives of the effectiveness of CFA in helping them catch errors and learn from peers. Survey of participants' perspectives on the potential for use and effectiveness of CFA in their own future classrooms.

Discussion & Implications

The continuous formative assessment (CFA) model is well-suited for online and blended learning environments. Online learning has always been suspect because instructors have been unable to measure the level of student engagement nor verify that the individual answering summative assessments is the individual enrolled in the class. The CFA model has been shown to enhance accountability, providing a window into student engagement, and a profile of student thinking during synchronous online or in-person instruction.

The CFA model helps establish an environment that more closely resembles the professional learning environment in which colleagues share their ideas with each other and provide feedback and critique. An instructor can elect to make some or all of student contributions visible to the entire class. In such an environment, students can evaluate their ideas and contributions in light of those of their peers, just the way professionals share their findings and provide critiques of their colleagues' work.

Preliminary data from pre-service teachers indicates tremendous enthusiasm for the CFA model, and dramatic improvements in collaborative online technologies suggest that these strategies will continue to grow in popularity. The move away from traditional print resources towards computer-based learning suggests an increasing familiarity with the technologies that support CFA. For example, South Korea announced that it intends to replace textbooks with tablets by 2015 (Kim & Jung, 2010). This trend is expected to grow worldwide, and with it will come increased understanding of and access to the technologies necessary for CFA.

Conclusions, Recommendations, and Future Research

The CFA model provides a mechanism by which instructors of online and blended courses can assess the learning of their students during synchronous instruction. As instructors analyze student data, they have an opportunity to adjust their instruction to immediately meet student needs. As a result of increased accountability and engagement, it is anticipated that students will perform better and be less likely to fall behind or drop out of online and blended courses. Although there are a variety of research initiatives underway at the university where this pedagogy was developed, it is clear that more research needs to be done in other institutions and settings.

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