

AC 2009-1440: APPLICATION OF MULTIMODAL SOFTWARE TOOLS TO TEACH PROBLEM SOLVING SKILLS

Paul Blowers, University of Arizona

Paul Blowers is an associate professor in the Department of Chemical and Environmental Engineering and received his PhD from UIUC in 1999. He has been selected as one of the top two teachers in his home department every year for the last nine years, was selected as the best faculty advisor from the University of Arizona in 2008, and also received one of seven national faculty advisor awards from the National Academic Advisors Association in 2008.

Application of Multimodal Software Tools to Teach Problem Solving Skills

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Many faculty members have attempted to apply new technological advances in classroom settings to improve pedagogical approaches, increase student learning, and to run classrooms more effectively. Unfortunately, many of the approaches of applying these new tools do not accomplish these goals. This work investigates the use of multimodal (spoken verbal, written verbal, and visual) approaches integrated through Microsoft's OneNote program to change student access to problem solving frameworks in the context of a sophomore engineering course.

One of the challenges in early engineering education is getting students to move beyond plug-and-chug type solutions and frameworks to having them fully integrate new knowledge into an independently organized thought process for bringing complex information to bear in applied ways. Students have a difficult time developing these skills from textbooks because the texts are not interactive and because they often do not present information in more than one way (written verbal). Lectures can engage students in active learning techniques where students can apply information with guidance. However, the fast pace of some lecture materials will leave weaker students with little recourse other than to extensively rely on the textbook. Archived materials from lectures recorded with OneNote accompanied by verbal spoken explanations timed with the flow of the note development allows students the ability to review notes at their leisure and to capture the nuances of explanation they may have missed during the actual lecture. Examples of materials generated for the sample course and a brief tutorial of how to apply the software will be discussed.

Time based analyses of student access to materials indicates some interesting trends that can be used diagnostically to improve lecture delivery, timing of materials, and student access. Analyses will investigate students who have English as a second language to see if their use of the materials is heavier than others, possibly indicating areas where they should focus improvement of their aural comprehension skills.

Introduction

The history of education is filled with innovation in approaches for enhancing student mastery of material while also allowing more efficient delivery of instruction. New technologies in the classroom are often attractive to faculty members because they can be used to foster learning in ways that are not possible through a traditional lecture style format. As instructors, faculty have moved from the not so distant past of writing on a black board, to writing in multiple colors on a white board, to using overhead projectors with preprepared slides, to using overhead projectors with PowerPoint[1], to using television sets in classrooms to watch videos in person or from distant classrooms[2, 3], to now using streaming video of lectures[4, 5] for asynchronous distance learning. Each innovation has been made to either remove a constraint from a learning environment, i.e., the instructor and student are in physically different places, or to improve the best of the current learning environment, i.e., involving students with hands-on computer simulations of new material instead of treating the information statically.

A brief look at the history of television suggests that one should use caution when approaching the use of new media for education. In 1959, the National Association of Educational Broadcasters said that "television can improve the quality of instruction"[6]. At about the same time, Poole claimed that "it is appropriate that science itself should have developed television, a medium perfectly suited to the promulgation of scientific knowledge"[7]. While there have been many attempts involving television in learning, most have not been successful in their goals of fostering education. For example, McSharry and Jones found that while science-based programs in the UK made up 5.36% of all broadcasting time, only 0.2 % percent of the programs watched by the general population came from this subset. When the public has access to science-based programming, they appear to chose other content for their viewing time. Just because a new technology has promise for enhancing educational opportunities does not mean that that promise will be fulfilled.

However, technologies can be used appropriately for enhancing instruction. For instance, Koeber and Wright showed that using technology to provide distance education did not lower exam scores in a sociology course, but did lead to lower student evaluations of instructor skills[2]. Another study by Chenkin, et al., showed exam scores were unaffected when students used an online-website to learn procedures in ultrasound-guided vascular access training versus a didactic lecture[8]. Exam scores were only 2 % different between the two groups. There are many other appropriate uses of innovative instructional tools, but they are not discussed in this work.

Some of the more successful innovations in instruction work because they allow the presentation of material in new ways that students find more accessible to their native learning styles[9-12]. Examples of this include the successful integration of laboratory exercises or simulations in course like chemistry, physics, and engineering[13] to allow students who are more "hands-on" or are sensing students to practice the concepts in the ways they learn best. One quantitative study showed that students raised exam scores by an average of 16 percent on a straight scale when they were exposed to a simulator of signal processing equipment in electrical engineering[13]. Other examples include using instructional videos or demonstrations on streaming media that allow visual learners to benefit most from their strengths, as shown by Howard-Quijano, et al., where they found a 14% improvement in tracheal intubation by novices when video instruction was provided in addition to traditional educational methods[3].

Much work has been done that indicates that multimodal learning is best [14]. Redundancy between oral and written modes, in particular, is one way of strengthening recall[1]. Students who access the same material through a variety of experiences, i.e., reading, solving, watching, and exploring in a laboratory, have the most positive cognitive development in the topical area. While access to information is important for creating learning opportunities, students' approaches to learning also have a large impact on their performance.

Students can either chose to learn material at a superficial level, almost as if information is just factual, or they can attempt deeper learning through contextualizing the information and assimilating it into a framework already existing in their minds [15]. For instance, Sket and Glazar make reference to high school chemistry students who did not organize their knowledge.

While students knew individual reactions, they were not able to link a series of reactions together to form a synthesis pathway[16]. Students in courses that make up the prerequisites for engineering may be attempting to learn superficially, leaving them with a weak foundation for future coursework. This view of teaching and learning was investigated to see if some faculty see teaching as transmitting information and students' learning as receiving this information[17], without much focus on how the information really functions. Hendersen, et al.'s work used a physics problem to focus an investigation into faculty perceptions of teaching and learning problem solving. The problem required an average student to use exploratory decision making as opposed to an algorithmic or "plug and chug" approach. Many faculty were oriented towards the algorithmic approach instead of focusing on problem solving; "Much of the material in prerequisite courses prior to the beginning of core engineering courses is oriented greatly towards fact recall and concept foundation building"[17] was one quote.

The essence of engineering is problem solving within constraints. Using multimodal approaches instruction should lead to enhanced problem solving abilities and stronger performance in assessment tasks that are not factual recall-based. In this work, a summary of student use of an on-line archival of lecture materials that were multimodal, including visuals, stepwise problem solving examples, graphical plots, and verbal recordings, are detailed. How students used the archived materials is investigated in addition to trends of use over time. Barriers to use are hypothesized and new approaches for fostering enhanced learning opportunities in the future are then described.

Course Details and Introduction to OneNote and its Multimodal Capabilities

The Course:

The sophomore material and energy balances course investigated in this work had an enrollment of a total of 94 students who finished the course out of the 103 who began the course at the beginning of the Fall 2008 semester. This course is the first core course in chemical engineering and is one of the two options engineering management students must take in order to satisfy their energy-based curriculum content requirements. Students in engineering management may take this course during their sophomore, junior, or senior years, while chemical engineers will all be classified departmentally as sophomores.

A variety of instructional support tools were used in this course that had an impact on the use and evaluation of multimodal tools in student learning. These tools were primarily computer-based and included the use of Desire to Learn (D2L), a comprehensive tool for organizing course information and tracking student use of online content, and the use of OneNote, a software program that utilizes PCTablet technology to allow one to write on a virtual notebook page while recording verbal statements made during class, and Microsoft Excel, Word, and Powerpoint files posted on D2L.

OneNote and Its Visualization and Verbal Recording Tools:

As discussed earlier, one of the possible benefits of using OneNote is that it can be used to combine visual and verbal information in a unique way to foster student learning. Figure 1 shows a screenshot of the second lecture where the instructor embedded an Excel file in

OneNote, embedded a pdf document, and embedded aWord document, all in the context of the material. Arrows point out some of the features of the interface.

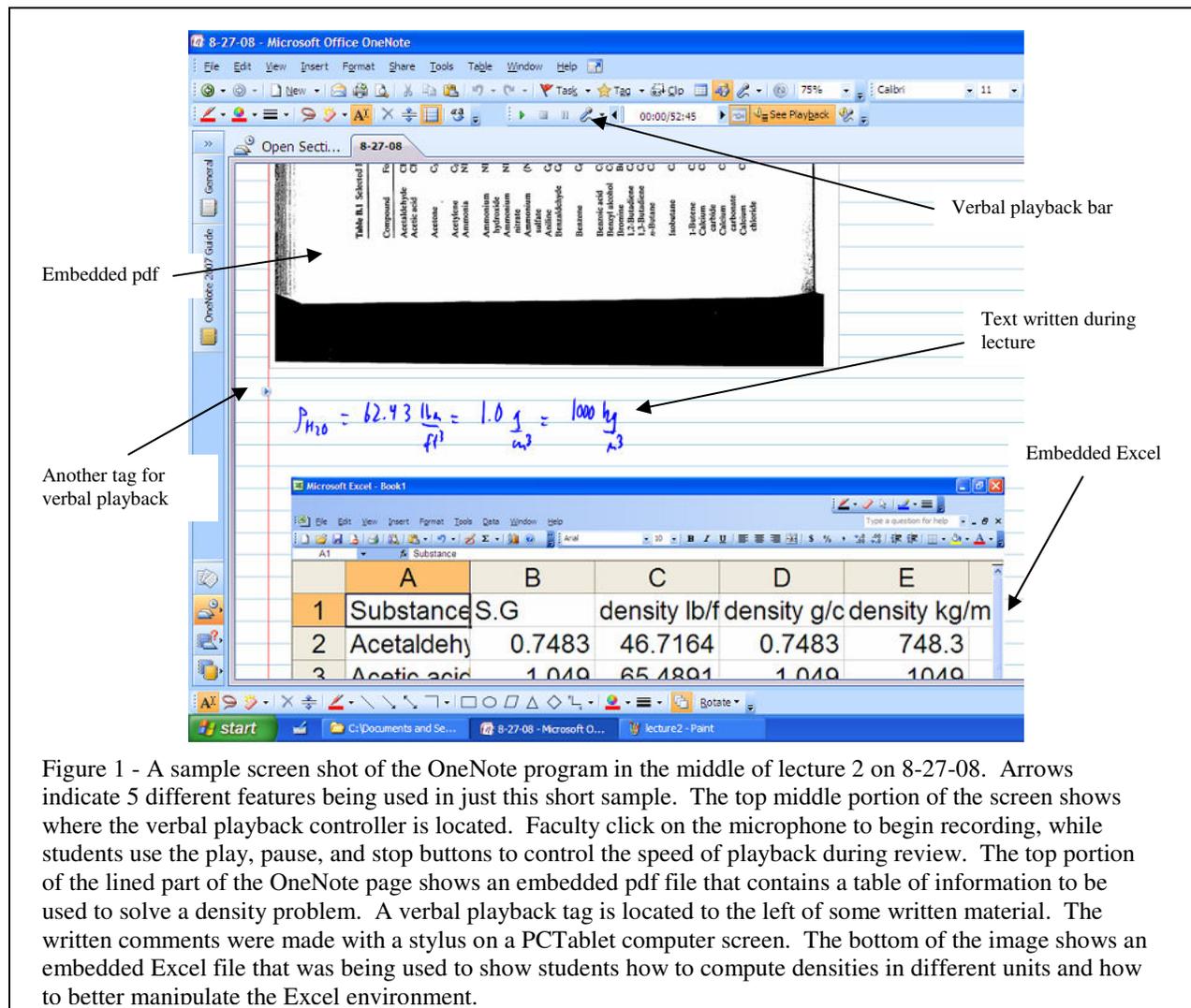


Figure 1 - A sample screen shot of the OneNote program in the middle of lecture 2 on 8-27-08. Arrows indicate 5 different features being used in just this short sample. The top middle portion of the screen shows where the verbal playback controller is located. Faculty click on the microphone to begin recording, while students use the play, pause, and stop buttons to control the speed of playback during review. The top portion of the lined part of the OneNote page shows an embedded pdf file that contains a table of information to be used to solve a density problem. A verbal playback tag is located to the left of some written material. The written comments were made with a stylus on a PCTablet computer screen. The bottom of the image shows an embedded Excel file that was being used to show students how to compute densities in different units and how to better manipulate the Excel environment.

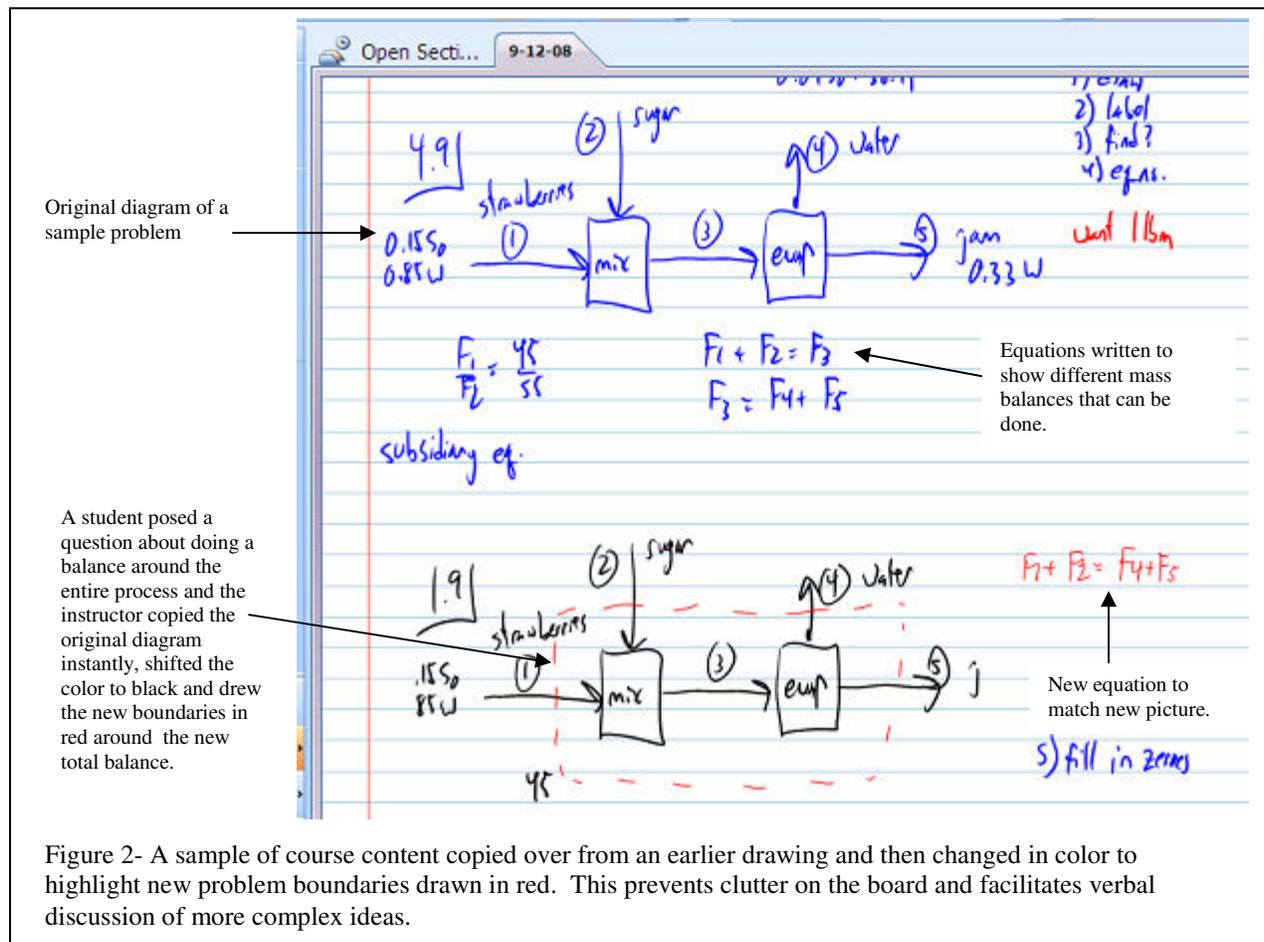
The instructor used the microphone icon on the verbal playback controller to begin recording sound during the lecture. One can use a microphone built into the PC Tablet for recording, or may purchase a lanyard-based microphone that can be worn while being mobile in the classroom. This type of microphone broadcasts to a USB port attachment at the laptop and can reduce background noise, depending on the model.

Students use the verbal playback controller to be able to scan the lecture material chronologically. Clicking on the time in the box moves the student verbally to that portion of the lecture and reorients the content material to match that point. Students may use the play, stop, and pause buttons to also control the movement through the verbal content. OneNote automatically inserts tags into the OneNote file each time a new action is taken on the screen by the instructor during a lecture, like beginning writing after a short pause, adding a screenshot, embedding a file, or rehighlighting some past material in a prior section. A sample verbal tag

appears to the left of the written text in Figure 1. Students can click on these tags to automatically begin the verbal description and work through that material again.

The sample screen shot also shows an embedded pdf file and embedded Excel content showing students how to manipulate an Excel spreadsheet. It should be noted that all of these materials were embedded on the fly during the lecture. Ahead of the lecture, the pdf file was scanned from a textbook, but the Excel file was constructed during discussion of the material and how to better solve an upcoming homework problem. That is one of the unique strengths of the OneNote interface; the instructor does not have to spend extensive time mapping out the lecture or how to use the technology as it is intuitively easy to manipulate.

One feature of OneNote that has been extremely useful is the ability to copy, move, and manipulate information quickly during a lecture. It is often useful for instructors to have a fresh copy of a diagram or a new rendition of an equation after many notes and caveats have been added to an original. In OneNote, one can "lasso" the content and copy it to a new section of the page before beginning to annotate it, often changing the colors of the copied material to highlight new information. This was used to good effect in the course when solving complex material and energy balance problems, as shown in Figure 2.



Some OneNote features are attractive for both students and instructors. It is often frustrating for instructors when the lecture has moved on to a new topic or enough time has passed that they have erased the board and then a student asks a pertinent question that could have been more easily answered before the key equation or important diagram on the board had been erased. It is laborious for instructors to verbally describe the answer in a way that students can access since the instructor is now talking about information that is not visually in front of students. While students may have archived the diagram or information in their notes, the discussion is difficult to control to ensure students are involved in the nuances of the explanation. In OneNote, however, the instructor can just scroll back up in the lecture content and then click the stylus on the section they will be discussing. Their verbal explanation then has a tag to start at that point and their appended written comments appear on the screen to show students exactly what is being discussed and its context. For students, this saves them the trouble of redrawing or adding to an already complex diagram.

One final attribute of OneNote will be highlighted before moving on to the time-based analyses of student use of the electronically archived OneNote files and implications for student success with this preliminary work. The last ability of OneNote that has clearly stood out after two semesters of its use in engineering courses is its ability to archive discussion-based materials where student input and wider-ranging web-based content can be shown in a connected manner. Figure 3 shows a series of small snapshots from the same lecture where information literacy was being introduced in the context of the sophomore course. One of the most useful parts of lecture is the give-and-take discussion of new ideas with students based on where they are in their knowledge formation.

When instructors typically launch into a discussion, they may then move to accessing content with a classroom based PC or their laptop. Most students can't quickly archive all the details of the material presented to them on the fly, or how to even access that material again as websites are difficult to describe, and addresses are long and small on most computer screens. Students also have a hard time focusing on archiving all the information from both verbal and visual sources at once.

Finding library information...

The University of Arizona Library

Central Search: Quick Search for Books & Articles

SEARCH & FIND

SERVICES

AFFILIATED SITES

NEWS & EVENTS

Getting Started Latest Headlines

- CIS Congressional Universe - Guide
- CIS Statistical Universe
- Citation Indexes - Guide
- Civil War Letters and Diaries
- Classical Music Library
- Classical Music Reference Library
- Classical Scores Library
- and Experimental Rheumatology On Line
- anea Mathematica

ISI Web of Knowledge [v.4.3] - Web of Science Home - Mozilla Firefox

Web of Science

Search Cited Reference Search Advanced Search Search History Marked List (0)

Web of Science®

Search for:

Example: oil spill mediterranean

AND

Example: O'Brian C* OR OBrian C*

AND

Example: Cancer* OR Journal of Cancer Research and Clinical Oncology

Search Clear

Lecture material starts with the main library page and then a screenshot shows the link to go to to get to peer reviewed article searches. The red arrow and C indicate what to do on the next page.

The next page shows what to click on from the list of C-options on the linked page from the above actions.

The resulting page and verbal discussion on what students do to enhance their search abilities using this library tool.

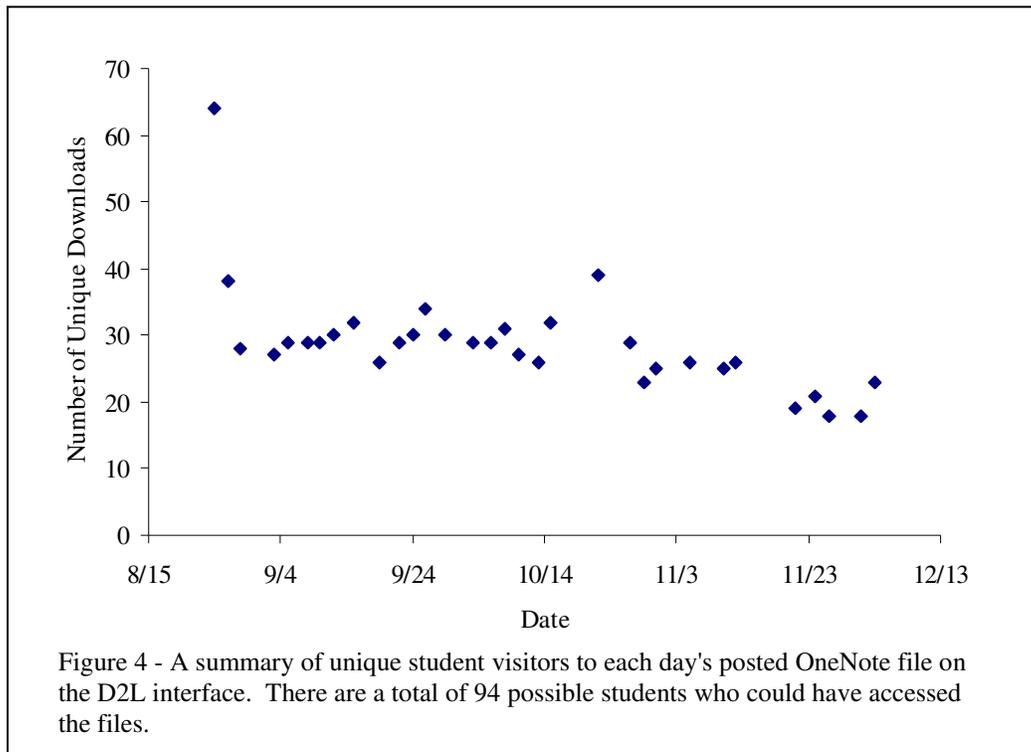
Figure 3 - Showing use of OneNote to archive discussion of how to find information on a university website using the verbal recording, screen shots, and use of diagrammatic indicators to show students the actions they should take. This lecture was accessed by 29 unique student visitors.

Time-Based Analyses of Student Access and Topics Covered

The D2L interface is powerful because of the many ways of placing material, linking the information with relevant connections, and in constructing pedagogical approaches that can provide feedback to students in real-time. However, there are some limitations of the D2L interface used during the course to track student access of materials. The software tool records the last date that a student visited the D2L content, typically one electronic file (i.e., PowerPoint

file, Word file, Excel file, pdf, or OneNote file). Also recorded is the number of visits each student made to the materials. So, if a student downloaded the material more than one time, only the last date will be recorded in addition to the number of times the student downloaded the file total and the average time spent accessing the content. This may cause some difficulty in analyzing trends if students were multiple visitors to the same content, as discussed below.

Figure 4 shows a plot of the number of unique visitors to each OneNote file that was posted to the internet on the D2L interface.

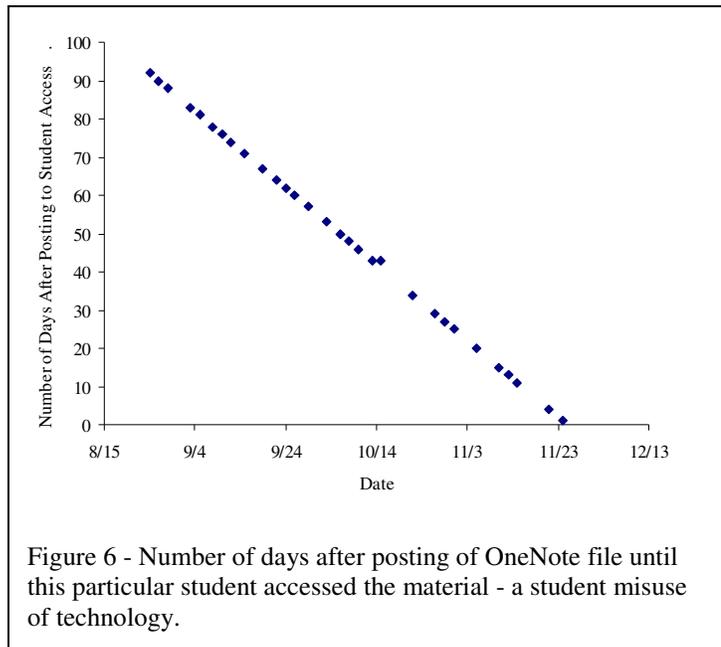


We see that the most accessed file for the semester was the first OneNote lecture when 64 different students downloaded that electronic file. That class focused on the course syllabus including course policies, exam dates, and an introduction to sustainability which would be a theme of the course throughout the semester through discussion on current newspaper articles. Thirty-eight different students downloaded the second lecture which began the technical content of the course through problem solving exercises. This day also involved embedding an Excel file in OneNote, embedding a pdf document and embedding a Word document, all in the context of the material, as discussed previously. On average, 29 unique visitors accessed each OneNote document at some point after it was posted.

There is an interesting spike on 10/22/2008 when a total of 39 students, 10 more than the average, accessed that particular lecture. The spike continues up and down in both directions

reflective student who made use of the OneNote and D2L combination of access in a timely manner. A review of this student's records show that they finished the course with the sixth highest score out of the 94 students completing the class. As a side note, this student has an overall grade point average of 3.711, indicating they are a strong student in almost every class and that their thoroughness in accessing material is probably a strategy they follow in most courses.

In contrast to the student access shown above, a diametrically opposite set of student data is also available from the D2L records and is shown in Figure 6. This student accessed all but four of the OneNote files exactly one time, and no file more than once. The ones they did not access were lecture materials posted from 9/19/2008, and then the last three lectures of the semester. Every file that they downloaded was accessed on 11/25/2008. The last three lectures the student did not download were all uploaded after the date of their access. The D2L Access records indicate that this student spent 91 minutes downloading the OneNote files. A review of student materials show that



this student received the sixth lowest score in the class out of 94 students. There are some implications of the student use patterns revealed by the data. First, the student in question may have few skills in reflective learning, the ability to look back on their performance or to develop a strategy to improve performance. The fact that this student did a one-shot pass at downloading all of the content in the week before finals shows they did not treat the access to OneNote reflectively as a way of mastering material. In fact, if the student had reviewed all 29 files they had downloaded, they would have spent 1450 minutes (slightly more than 24 hours) listening to the material and trying to absorb it all right before the final. Not surprisingly, this student maintains a 1.461 grade point average. There was also another student who had the same access patterns who performed slightly better in the course, mainly due to a higher exam average, possibly because of stronger exam taking skills.

It is interesting to compare the student access from Figure 5 to the one in Figure 6 in other ways. On average, the student represented in Figure 6 spent an average of 3 minutes per access time to the OneNote file, indicating there was no review of the material and that the access was just a brute force download. On the other hand, the student represented in Figure 5 spent an average of 11.59 minutes reviewing each file and scrolling through it instead of just 3 minutes. The high ranged from 59 minutes to a low of 3 minutes, where they were also just downloading and not reviewing the material. The extra time reviewing indicates either a higher value of total time

Figure 8 shows data for a single student with the four exams and final indicated with the vertical lines like in Figure 7. This student spent significant time reviewing 17 of the lectures, spending between 5 and 54 minutes on each of those files. This student performed well on exams except for the final. It should be noted that their lowest score on an exam was for the first exam. This plot empirically suggests that this student used the OneNote tool in useful ways that enabled them to improve their exam scores on the second, third, and fourth exams.

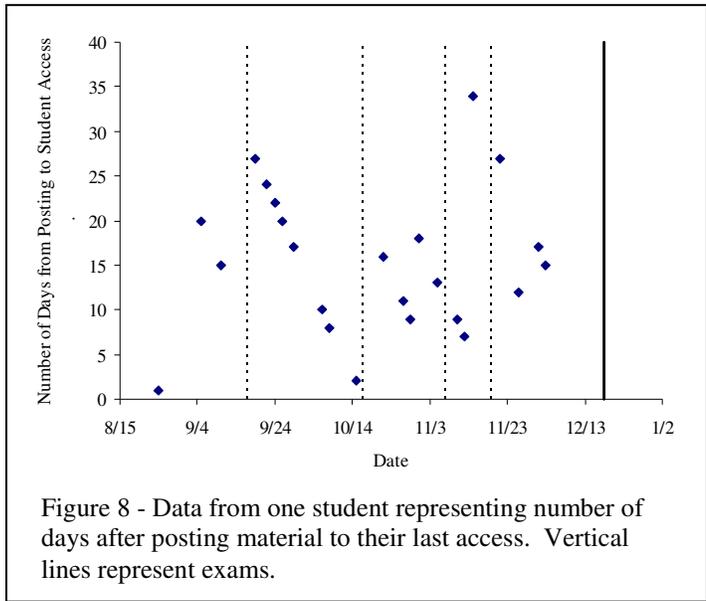


Figure 8 - Data from one student representing number of days after posting material to their last access. Vertical lines represent exams.

It was expected that the OneNote technology would have been an aid to students who were absent from class where students could have access to the material and listen to the lecture asynchronously. A rigorously attained attendance record verified by students who received course credit for part of their homework grade was combined with the D2L OneNote student access data to investigate this issue. Out of the 94 students, 31 had at least one absence during the semester. Of those, 19 had more than one absence and only this data will be used in this section. It is not only the question of whether students visited the material for the days they missed, but also their other patterns of OneNote access that are interesting.

The discussion above can be furthered by considering Figure 9. The data here are again only for those students who missed two or more absences, with a total of 19 students out of 94 falling into this category, and the individual students are represented as points on this plot. The x-axis represents the fraction of overall materials downloaded by a particular student while the y-axis represents the fraction of missed lectures where students downloaded materials. If students downloaded materials more frequently for the lectures they missed, then one would find them above the 45° line, while one would find students who had behavior unaffected by their absences on the dashed line. We see in the figure that only 7 of the 19 students downloaded materials more frequently than their baseline behavior in response to a missed lecture. Only 1 student accessed 100% of the materials for the days they missed and that was only two lectures for that student. Four students downloaded more than half of the lectures they missed, but the rest did not. Thirteen students did not access any of the archived content for missed lectures even if they did access other content during the semester. Again, there are no trends for downloading behavior compared to absences.

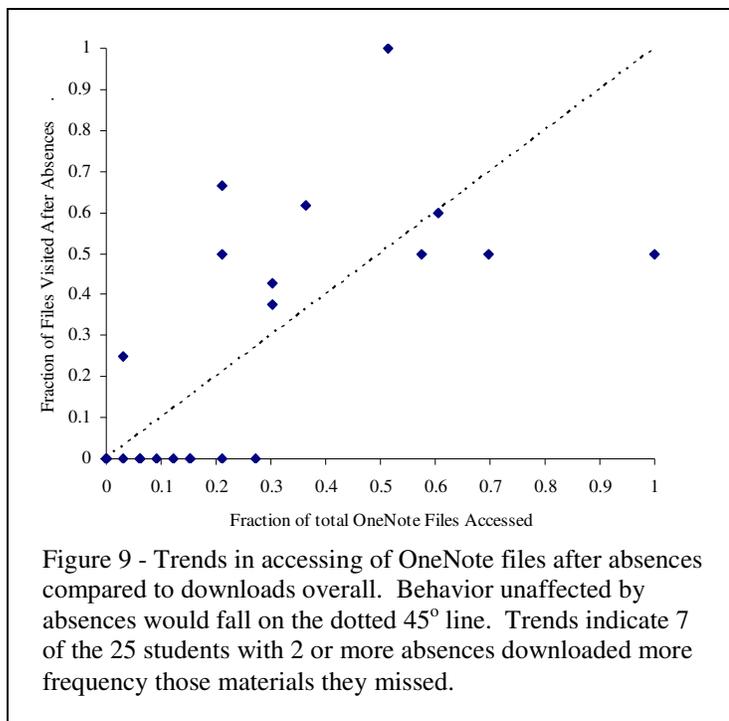


Figure 9 - Trends in accessing of OneNote files after absences compared to downloads overall. Behavior unaffected by absences would fall on the dotted 45° line. Trends indicate 7 of the 25 students with 2 or more absences downloaded more frequently those materials they missed.

It was suspected that students who had English as a Second Language would find the access to recorded oral information to be useful. Analyses of the available data did not indicate any trends regarding this hypothesis as those students had similar access patterns to the rest of the class. Perhaps more directed instructions and the potential value of using the archives may encourage ESL students to access the content. Future work should be done on this and other related areas.

Future Ideas to Improve OneNote Access and Use

This section details some thoughts on how to improve the access and use of OneNote files so students will more consistently think about using the materials for their educational enhancement. The data shown in this work is from a large sophomore level course where students may still be discovering their best modalities of accessing materials. The data in Figure 4 showed that far fewer than 100% of the students accessed the OneNote materials. This is despite the fact that large efforts were made prior to the start of the class to streamline the downloading and use of the program and supporting software. The instructor worked with an in-house information technology expert to create a handout for students on how to access the materials and vetted it with the teaching assistant.

Essentially, the students had to apply for a Microsoft Alliance identification descriptor, be approved, and then had to download the OneNote program to their personal computer. The alternative was to use the programs available to the 55 chemical engineering students in the departmental computer lab, or for all students in two different engineering discipline-specific labs where they did not need to get the preapproval and download the program; the program was already locally available on all of those computer lab computers. Two updates on how to access the materials were posted to the D2L site, one generated by a student who found some shortcuts and methods to enhance downloadability, and one from the TA who had trouble accessing the content when attempting that from home. Unfortunately, students who own Apple computers were unable to access the verbal content even when they did download the program and had access to the files. It is unknown what fraction of students this is as that data was not collected. It should be noted that the college strongly suggests that student purchase non-Apple applications and hardware to facilitate interactions with faculty.

A total of 11 students never accessed any of the OneNote files, including one student who is an information technology specialist with 10 years of experience on different computing platforms. An additional 12 students visited only one file recording a lecture, with 10 of them only superficially visiting the first day's posting for 1 to 2 minutes. It is not clear why students did not take advantage of exploring the learning opportunities the software could provide for them.

To increase student familiarity and to encourage students to try OneNote in the future, an early homework assignment will be created where a unique OneNote file containing a different keyword and verbal instruction for each student is posted to the D2L website. Students will then be required to go through the exercise of going to the website to access the information and report what their unique file contains. This should increase the number of students who become successful at accessing any of the material. The expected result will be that they continue to use the OneNote program after this assignment because the initial barriers to access have been removed through a required assignment.

Additional Future Explorations

Future work will investigate how student use of the OneNote and D2L access correlates with Felder's Index of Learning Styles. It is expected that students who are more visual will respond well and will access the visual portions of OneNote more frequently. Verbal learners or students that have language acquisition issues, i.e., English as a Second Language, may also make more frequent use of the verbal recordings. Data regarding both of these issues was not fully collected for this work, but will be collected in the future. It is feasible that student retention and learning accomplishments may both be enhanced through the availability of the tool for multimodal lecture archival described in this work.

The use of different materials to demonstrate the logical flow of exploration and problem solving steps was much easier to accomplish using OneNote over other instructional methods used by the instructor in the past. The interface was easy to use and Figures 1 through 3 showed how one could use multiple methods to demonstrate steps and information. Methods of evaluating the success of these materials will be explored in the future.

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