Learning to Read and Take Notes in Dynamics

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Introduction

ABET criterion 3i states the need for students to become life-long learners [1]. Part of being a life-long learner is the ability to effectively read engineering texts and other types of technical material and retain it in some way for future reference. Yet it is not uncommon for students to assert, “The lectures were great; I didn’t have to read the book,” thus losing an important opportunity to acquire skills needed for life-long learning. Although faculty recognize that the ability to effectively read and learn from technical material is vital, several factors can drive students away from “reading the book.”

For instructors, helping students learn effective reading or learning strategies can take a back seat to teaching content. Instructors focus on creating good lectures, knowing they will be evaluated on how well they teach. Students provide these evaluations. Instructors who rely heavily on students learning solely from a textbook and fail to lecture well violate students’ expectations and may receive lower ratings. Further, instructors, over a number of years, have developed their own strategies for effectively learning from a text. Yet they may be unable to identify those specific strategies and convey them in ways that make sense to students.

Second, students are under significant time pressure and are prone to cut corners, however unwise it is to do so. Reading a textbook seems inefficient if one’s goal is to complete homework, particularly if the text is poor or the subject difficult. Students can confuse finishing the homework with developing a strong understanding of the concepts.

Textbooks can also prove challenging, even when students do read them. Not all textbooks are easy to learn from and students’ avoidance sometimes makes sense. Weinberg and Weisner [2] argued there are several links between texts and readers that need to align for a textbook to effectively support learning. For example, links may be broken when a student lacks the necessary background knowledge or misunderstands how the textbook format functions. Or, the author may not have a clear understanding of the competencies of the intended readers. When any of these links are broken, a student can have difficulty learning from the text.

Finally, while students may have received some instruction in reading, note-taking, and other strategies, that instruction has generally occurred in English classes. Many believe that study skills are generalizable and effective across disciplines so little disciplinary support is needed [3], [4]. In essence, these general skills are considered to transfer easily across disciplines. Yet transfer does not appear to be the case. Effective disciplinary reading requires specific skills [3], [4]. Shanahan, Shanahan, and Misischia [4] noted many secondary disciplinary instructors do not know how to support their students’ disciplinary reading and thus do not teach the specific study and reading skills needed. As a result, instructors often avoid using a text and just tell students what they should know [4]. Thus, students come to university lacking discipline-specific reading and study skills for learning from textbooks.

Given this background it appears that STEM students, in particular, may experience significant challenges learning from textbooks and other technical material. Academic success centers may provide coaching in general study skills but often do not provide resources in the necessary

disciplinary study skills. Thus, students can be at a disadvantage in the technical courses common in STEM.

This qualitative case study examines how students learned to read the textbook and take notes in an engineering dynamics class. The intent of the study was to identify strategies and perspectives that would aid instructors in incorporating reading and note-taking effectively in their courses.

The class had four students and was run as a seminar. Each session consisted of joint problem-solving of review, and then new, problems. Between classes the students completed graded homework on previous problem types, read the textbook and took notes on the content and problem types of the next section, and then attempted some new problems. Aspects of reading and note-taking were occasionally discussed in the class and the students completed online journals reflecting on what worked and what did not regarding their own learning. The journals were retained as data and analyzed with qualitative methods based on inductive content analysis.

Literature review

If one does an internet search on “how to read a textbook” a plethora of sites come up. Many of these sites are created by academic success centers at universities. Suggestions include excellent strategies, such as previewing the material before reading more closely, as well as strategies that are not supported by research, such as rereading and massed practice [5]. Very few of the suggestions addressed reading technical material such as found in math, science, and engineering textbooks.

There is a collection of academic research focused on creating proficient readers. Most of this research addresses teaching K-6 students to read well. A much smaller collection characterizes what expert adult readers do. A very small subset addresses what readers of technical material do. Some of these studies compare the practices of expert readers and novice readers. Novice readers in this case can be understood to be those new to a discipline, such as undergraduates.

Expert and novice readers

Pearson, Roehler, Dole, and Duffy [6] focused on developing a curriculum to create expert readers in any discipline. They compared expert and novice readers with a goal of improving comprehension. They noted expert readers:

- Made connections between new and prior information.
- Learned to distinguish important from less important ideas in the text.
- Were able to synthesize information within and across texts.
- Asked questions of themselves and the authors as they read.
- Made inferences during and after reading.

Brown, Roediger, and McDaniel [5] concurred with these characteristics, noting these types of activities supported deeper and more effective learning of the material. In particular, they noted self-testing, rephrasing of key ideas, and mixing up the practices of recall all improve learning.

Pearson et al. [6] went on to develop several strategies for those wishing to create expert readers. While they offer a number of suggestions, two are relevant to this paper. First, good reading strategies adapt to “the text, the task, the purpose, and the consequences of reading.” Second, instructors should think of their task as apprenticing novice readers into the text rather than acting as authorities.

Weinberg and Weisner [2] contrasted expert and novice readers in mathematics. They maintained expert readers actively construct meaning as they read, relating the text’s ideas to their own knowledge. In essence, they carry on a conversation or a transaction with the text. Novice readers, however, read instrumentally to achieve a goal, such as completing homework or studying for an exam. They view the goal of the text is to transmit knowledge and hence engage in little conversation with the ideas contained in the text.

The specific discipline being studied may have a strong impact on what strategies one uses when learning from a text. Shanahan and Shanahan [3] argued that “disciplinary literacy” be taught beginning in middle school. Disciplinary literacy emphasizes the “knowledge and abilities possessed by those who create, communicate and use knowledge” within a specific discipline. For example, different reading skills may be needed when learning from a history book and a math book. Those skills should be explicitly taught so students become adept at working with disciplinary material.

Bucciarelli [7] agreed, asserting different disciplines manifest different “object languages.” These object languages are based in discipline-specific conceptual worlds. For example, different engineering disciplines have different object languages, which can make interdisciplinary work challenging. These object languages consist of discipline-specific terms and the understanding of these terms and discipline-specific norms, such as the meaning of “quality.” They will include relevant formulas, time scales, and metaphors.

The difficulty with an object language is that it masquerades as one’s own native language. For example, since one is using the object language to create descriptions in English, one is tempted to think that everyone understands the description because it occurs in English. One does not realize that the description is actually occurring in the object language. Students or novices who may not be adept at the object language fail to understand what is being conveyed. Since texts are created by experts, novices can struggle to access the information in the text.

Shanahan, et al. [4] analyzed the differences between expert readers in history, chemistry, and math. While the expert readers in chemistry and math had some overlapping approaches, expert readers in history were starkly different. Differences included how the expert readers viewed authorship, reliability of information, historical context, and the use of graphic elements. The authors also noted different disciplines have specific vocabularies, ways of communicating, and quality standards that determine the types of writing and reading skills needed. Since expert readers differ in their approaches to disciplinary texts, generalized study skills may not transfer easily or well.

It would appear from this literature that engineering students need to be explicitly taught effective approaches for reading and learning from technical material. The question then

becomes one of what types of skills help one learn from a text and how to use them in a disciplinary setting. Taking notes on technical material is one possible skill.

Note-taking

While there is literature on fostering writing skills in engineering students, that literature generally does not address effectively taking notes on texts to learn course material. Further, much of the research on note-taking examines how students take notes on lectures. Little is focused on how students may take notes on texts or during problem-solving sessions. However, some concepts are important in both domains.

Note-taking, whether in lecture or out of a text, has two important functions. First, it supports learning the content. Second, it provides a way of preserving the information for later review for exams and/or completing homework assignments. Students who take notes generally perform better in a course than those who do not [8].

Kiewra, Benton, Kim, Risch, and Christensen [9] stated that note-taking has two important pieces. The “process” is the recording of notes. The “product” is using the notes for some type of review or completing homework. Students struggle with the note-taking process during a lecture. Left to their own, they only record about 30% of the concepts, with poor organization. When using structures provided by the instructor, such as guided outlines or matrices, the number of concepts climbs to about 40% and organization improves. The authors noted strong, well-organized notes improve performance on tests. Well-organized notes serve to link concepts, enhance recall, and support learning. However, the authors noted that students using flexible outlines outperformed those who used outlines that were highly structured.

There are many ways to take notes, whether from lecture or text, but not all are equally effective. Strategies range from verbatim notes, which take little student engagement to various types of “conceptual note-taking” such as reflective inquiry, prediction/testing/reflection, and self-explanation. These methods require the student to engage more deeply with the material. The more students engage with the material, the better their performance [10].

One of the most common strategies for conceptual note-taking is called self-explanation. In self-explanation the students actively integrate their new knowledge with their old by explaining the content to themselves, whether from lecture or text [11]. Chi, Leeuw, Chiu, and LaVancher [11] showed that “high explainers” or those who demonstrated the greatest number of explanatory statements on a topic, performed better on a test than “low explainers.” Further, in this study, participants were merely prompted to self-explain rather than trained in how to do it. Thus, self-explanation during note-taking appears to be an accessible strategy for students.

Trafton and Trickett [10] explored how students used note-taking to support complex problem-solving. Students who took notes during the problem-solving process were more likely to reach the correct solution. The authors found strategies using forms of self-explanation were more effective than strategies that did not. Additionally, they found that those using free-form notes during problem-solving rather than structured note strategies provided by the researcher were more apt to solve the problem. The authors believed that free form notes more strongly support

self-explanation, which resulted in better problem-solving. In essence, spontaneous self-explanation works better than self-explanation that is prompted or guided.

How the notes are used after the fact is also important. Students who reorganize notes or engage in types of self-quizzing will perform higher than those merely reading through the notes passively [5], [12].

Note-taking can be an effective strategy for learning from a text. However, the type of note-taking strategy and how the notes are used after the fact has a strong impact on student performance. Less structured strategies that support self-explanation lead to higher performance.

Study context

The study was conducted in a class of four engineering juniors at a small liberal arts university. Since the class size was small, the instructor opted for a problem-solving seminar format rather than a traditional lecture. Each session began with working problems on the white board from the previously completed homework set (online and graded). These problems were presented by student pairs and the instructor commented and/or clarified each solution as needed after presentation.

In the second half of each class period, student pairs presented problem solutions on the board for the upcoming topic. Prior to class the students had been asked to read the content section of the textbook for the upcoming material, take notes, and attempt a few fundamental problems. This work did not count towards their grades, however the students were motivated to complete the tasks since they were called upon to write solutions to these problems on the board. At times the students were not able to solve specific problems and the instructor helped the students over difficulties they had encountered. A general class discussion of each problem type followed each presented solution.

Following class, the students completed homework problems (graded online) of the type presented in the second half of the class session. The students then read the textbook for the next topic, took notes, and attempted problems.

At the beginning of the course, the instructor (one of the researchers) announced that the class was going to learn to read the textbook, take notes, and do problems. He described the value of being able to read and take notes and that learning the strategies was in their best interest for further studies. Students were then asked to complete the first journal entry, which explained their initial reading and note-taking approaches.

Within a session or two it became clear that there was no consistent approach among the students in terms of what they actually took notes on. The students were then asked specifically to:

- Capture the important equations in the assigned reading, always including the conditions (such as constant acceleration) when they apply.
- Capture simple figures to make variables, such as vectors, clear.
- Capture when or why to use the equations.

They were then to journal on the difference (if any) these strategies made to their learning.

Within another few weeks it became clear that much of the content of the textbook was in the example problems. Students were explicitly taught to work with examples in the following way:

1. Think about how you would approach the problem as you follow the author's steps. Take special note when the author heads in a different direction than your normal inclinations. This is an opportunity to learn a new technique.
2. Note the order of the basic steps the author uses to solve the problem.
3. Note any special tricks the author uses. By tricks, we mean clever short cuts that save time or calculus. For example, recall the use of implicit integration when one had $y=f(x)$ and one wanted $x\text{-dot}$ and $y\text{-dot}$?

They were then to journal on using this approach.

After the first exam it became clear that some students had difficulty determining how to approach a problem. The students were asked to journal on what steps they used when they were stumped.

- When you look at a problem, what is your mental strategy for recalling the steps to do the problem?
- When you get really stumped on a problem, what are your mental strategies for finding a path to the solution?

Following journal prompt 4, one of the researchers created a problem recognition and solving strategy from the aggregate thoughts in the journals. An instructional handout was created detailing a problem-solving process. These strategies were used for Exam 2 review. A copy of this handout is in Appendix B.

Appendix A lists the complete journal prompts. In summary, these prompts asked:

- Journal 1: What is your current process of reading and taking notes?
- Journal 2: How well did taking notes on equations, figures, and when to use equations help you complete problems?
- Journal 3: How did taking notes on example problems help you solve problems?
- Journal 4: How do you get *unstuck* on an exam problem? This journal followed an exam and led to a *note-taking for problem recognition and solving* handout shown in Appendix B.
- Journal 5: How has your note-taking changed? How has it affected your ability to recognize and solve problems?
- Journal 6: At the end of the course, students completed a short questionnaire, enabling them to reflect on their participation and to offer suggestions for improvement. The questionnaire content is included in Appendix A.

The data from the journal prompts and the questionnaire is included in the Results section below.

Methods

This naturalistic study was conducted within the class as described above. The journals, which were simply a part of the normal structure of the class, were collected as data. These journals were analyzed using qualitative methods. Since this study was exploratory, a descriptive approach seemed most appropriate [13]. Furthermore, since the journals are a form of the students' verbal communication, being able to create descriptions was important [14]. Qualitative research employs a wide variety of methods. We selected a multiple case study approach. Case studies examine bounded, integrated systems and multiple case studies often have small sample sizes [15], [16], [17]. Each student constituted a case. As noted above, there were four participants in this preliminary study. The goal was to identify factors within the cases that may be transferable. Any factors that were identified would require further study.

However, a case study method does not specify how the data is to be coded. Since the data consisted of journal entries, we used content analysis to code for manifest (obvious) themes. Content analysis is used to examine the content and meaning in texts. The term *text* is used broadly and refers to documents or communication "produced by someone to have meanings for someone else" [18]. These journals were coded using *inductive* content analysis methods [19], [20]. These methods identify themes within the data and subsequently code the data into these themes, as opposed to *deductive* content analysis, which chooses themes a priori.

Before coding, a pseudonym was assigned to each participant and used throughout. Concurrent with coding of themes, a description was written to characterize each participant. These descriptions are presented in the results section. The emergent themes across the participants are combined with the literature to form the discussion section.

Results

Based on the responses in the students' journals we have created the following descriptions of each individual's approach.

Alan

Alan entered the course with no training in how to read or take notes on technical material. He stated his approach to reading for any class was inconsistent and based on the time he felt he had available, which was often 20-30 minutes per assignment. Sometimes he would read the text. Other times he would address certain sections he struggled with. However, he claimed the majority of the time he did not read the text at all.

When he did read, his approach was to "carefully read for pertinent information" and take notes on "formulas as well as important conceptual points." In technical reading he observed, "I find the hardest part of reading technical writing to be the embedded numbers, equations, and variables that I often mentally skip while reading." As a result "I only get the written information and miss all that the equations mean." He noted that working with the equations "takes more focus and intentional reading that I often want to commit to."

When Alan began taking notes as instructed, he claimed he was able to retain more information. He believed it was because he was reading the material more closely and that writing the

information down improved learning. He also maintained note-taking made it easier to find information in the textbook. After initial instruction, he stated “I don’t always write a lot, but the stuff I do write is super helpful.” These helpful notes included problem-solving strategies that were not obvious to him. He felt that through note-taking he was learning the process of how to solve the problems, which then made the homework easier.

Over the course of the semester Alan’s note-taking changed. “At the beginning my notes consisted mostly of equations. This was helpful because it made a nice formula sheet for attacking homework problems.” By the end he reflected “I have noticed more comments noting conceptual components. . . . I think this has allowed for me to not only understand the equations, but how they are used and the little tips and tricks that make them useful.”

Alan identified effective and ineffective learning strategies. Reading and note-taking, followed by close analysis of the sample problems worked well for him. However, “practicing the example problems before reading the solution [was] not effective enough for the time it took.” Additionally, some topics were too difficult to learn from the text alone. “Lecture was a more efficient way to learn the information” when the topics were difficult. Working difficult homework problems took a long time. “I battled through getting wrong answers, calculation errors, and conceptual misunderstandings.” As a result, he felt he had less time to read and take notes. He advised taking the difficulty of homework problems into account.

Brad

Like Alan, Brad had not received any training in how to read or take notes on technical material, although he admitted note-taking had been discussed in other college courses. His initial approach to reading the text was to read a section and solve the related problems, while reviewing the section as needed for help. “This helps me read through the book, while simultaneously solidifying my knowledge through practice.” He would then do homework problems, again referring to the book as needed. His note-taking involved writing down important definitions, formulae, further explanations, and “things that seemed important.”

As he received instruction in note-taking, he became “much more focused on what the conditions for the formula are, and any [related] figures.” This approach enabled him to “more easily check which equations work best with certain situations.” He claimed good notes enabled him to avoid returning to the book for help.

Over time Brad’s notes became more complex. “My notes usually include a clear and detailed diagram of the problem as well as any information required to know what the problem is about. . . . I also write out the steps.” Brad stated that sometimes the text omitted needed information. In that case he tried to identify all the numeric inputs and their sources. He claimed his ability in problem-solving and categorizing problem types has improved.

Brad maintained that instruction in note-taking helped his problem-solving ability because “I have been exposed to the tools that are necessary to do them.” However, Brad declared that “solving problems is the way I learn to recognize problems. It’s not as much as the notes that help me diagnose a problem, but my experience with that kind of problem. . . that are the biggest

factor.” For Brad, the notes provided a starting place. And, like Alan, he found that note-taking helped him remember where to find information in the text.

For Brad, the instruction on note-taking was effective because he was held accountable. “Explaining those problems to other students puts more pressure on students to learn the material more thoroughly.” However, like Alan, he noted that note-taking fell apart when the text became more difficult. “Trying to work through those problems on your own gets less and less realistic, since they are usually the first examples of the material that we see.” Again, like Alan, he suggested using more lecture for the difficult sections.

Chris

Like Alan and Brad, Chris entered the course with no training in how to read or take notes on technical material. He maintained that he entered with “decent” note-taking skills and spent 20-30 minutes per assignment. His approach was to skim through the material, noting equations and strategies, while paying brief attention to the examples. He stated, “[I] make sure to make notes on the important equations.” He thought he could slow down his reading and “be more intentional in learning the concepts.” After reading he would then proceed to the homework.

The instruction in note-taking did cause him to slow down, which he believed was beneficial. He looked at the figures and spent more time with the text. Like the others, he claimed that note-taking enabled him to find material in the text more easily. He tried problems on his own first, attending to his process, rather than reading through the examples.

Chris claimed that the notes helped him “have a plan heading into the problem.” His notes included various strategies gleaned from the examples. He also learned how to approach problems more effectively. Chris was focused on the homework. While reading and note-taking helped him learn concepts, he stated the examples “mainly help with my understanding of how to solve the homework problems.”

Chris appeared to struggle with maintaining his note-taking practice through the semester. As the work became more challenging and time-consuming, he reverted back to jotting down equations and short notes. However, he argued that note-taking improved his ability to categorize and solve problems. He stated, “There is definitely a correlation between my notes and my success in class” and “I need to get back to taking better notes. . . .”

For Chris, instruction on note-taking was effective because it caused him to slow down and it solidified his understanding. He felt note-taking would be helpful, particularly for those students transferring to a state school where class sizes would be larger and they would need to be more independent. However, like the others, he agreed that reading and note-taking alone were insufficient for difficult topics. Difficult topics should be well-supported by lecture.

Dan

Like the other students Dan entered the class with no training on how to read or take notes on technical material. He did recall brief training during high school English class, but stated “it was how to read an English textbook, which is significantly different.” His initial strategy for the dynamics text was to skim through the material, writing down all the formulae and the associated

words. “[I] write down the formulas and the words associated with them . . . go back to the beginning and try and figure out how the text tells me the variable relate to each other.” He estimated he spent about 15 minutes per assignment reading.

He found the instruction in note-taking helped him recall formulae more easily. He stated he no longer need to look for them in the book. He claimed he read the sections more closely since “I then formulate thoughts upon them.”

The note-taking instruction seemed to have less impact on Dan than on the others. He persisted in his original approach, but would then work through the examples, trying some easier problems. When the problems were easy, he would skip working the examples altogether. However, he stated. “The way I learn from examples isn’t the best. I look at them, follow the steps, and then move on. I don’t try and look for tricks.” He did admit that he noticed more tricks after note-taking and that he needed to pay more attention to those.

Although Dan appeared less willing to implement suggested note-taking strategies, he did claim his notes changed over time. He spent more time on the application of the equations. Being held accountable for reading and note-taking was a boon for Dan. He noted “I knew that some of the time I wouldn’t do that work and fake it and that ended up hurting me in the end.” Although he did not engage with the note-taking strategies he believed they would be useful next year when he transferred to a state school where there would be less support.

Dan agreed with Alan that working on difficult problems using only the text did not work well for him. Indeed, he argued that approach actually caused him to lose confidence in his abilities. “I would usually end up staring at them until the time I set aside for it was over and then continue on with less confidence.”

Thematic descriptions of responses to journal prompts

The student descriptions above chronicle their idiosyncratic approaches to learning to read and take notes from the textbook. To highlight the commonalities and differences among the students, their responses are now summarized by themes for each journal prompt.

Journal 1: What is your current process of reading and taking notes?

None of the students had any prior instruction in technical reading and note-taking. Their approaches to the tasks ranged greatly. For example, one student would work section-by-section interleaving homework problems, whereas another student only did homework problems after reading all sections from start to finish. As another example, one student spent time interpreting equations as encountered, whereas another student skipped past equations so that he could get the broad view of the concepts end-to-end in the text. Although each student used a different strategy, they did share one common trait; all viewed reading and note-taking as part of the larger task of learning to solve problems.

Journal 2: How well did taking notes on equations, figures, and when to use equations help you complete problems?

The four students all reported that they read more closely or slowly while taking notes. They did not directly relate this closer reading as helping them solve problems, but two reported that the closer reading helped them retain what they read and three reported that they could now find specific information in the textbook more easily. Though each experienced similar improvements, the improvements appeared to be extensions of their initial strategy.

Journal 3: How did taking notes on example problems help you solve problems? Did you learn basic concepts better from taking notes on examples?

The students' thoroughness with note-taking on example problems varied greatly. One student extracted detailed solution steps including rationale for each step. Another student took few notes on steps but identified key steps to a solution. Yet another student read the steps and "then move[d] on." All students reported that reading examples helped them learn problem solving steps, but not learn the underlying concepts. Again, the improvements related to their initial processes, which were idiosyncratic.

Journal 4: How do you get unstuck on an exam problem?

The detailed responses to this prompt varied widely. However, all students mentioned steps that would help identify the problem such as listing knowns and unknowns or drawing a diagram. Each mentioned hunting for a solution such as generating a general direction or finding an appropriate equation. Some offered problem simplification strategies such as solving for easily found variables first.

Journal 5: How has your note-taking changed? How has it affected your ability to recognize and solve problems?

All students reported that their note-taking had changed over the semester, from one student who reported a small change because he took good notes coming into the class, to another student who reported a big increase in the quantity and quality of his notes. All students reported that note-taking had increased their ability to recognize problem types and/or solution methods.

Journal 6: What proved effective and ineffective in note-taking?

Journal 6 was a questionnaire of eight questions. See Appendix A for the complete questions.

Only one student entered the course with prior instruction in note-taking, and this instruction was in a high school English class. The students' initial note-taking habits varied widely with the common trait of skimming the textbook and briefly taking notes. All cited different effective practices including attempting examples before reading the solution, deriving equations, close analysis of examples, and being held accountable. Interestingly two students reported that attempting example problems before reading the solution was a waste of time, though one student identified this as the most helpful approach. The student in the journals uniformly recommended adding more mini-lectures to supplement note-taking, and all students reported that the effort on reading and note-taking would help them in future courses.

Discussion

We have provided descriptions of how each student was impacted by the instruction in reading and note-taking, as well as a thematic analysis of their responses. The following discussion explores those impacts in more detail across all participants.

Reading and note-taking are instrumental activities

Throughout students' journals there was no hint of separating reading and note-taking from problem-solving. This lack of separation suggests that reading and note-taking were viewed as instrumental strategies for completing problems, and not as stand-alone learning activities. The instrumental status of reading and note-taking was further reinforced by the course grading scheme; homework and exams evaluated students' problem-solving ability. Consequently, from a curricular point of view it seems coupling reading and note-taking to problem-solving is the most natural approach, and any attempt to decouple them into stand-alone learning activities would be less effective. It also implies that the better place to embed reading and note-taking instruction is within the disciplinary content courses, rather than as stand-alone instruction.

Reading text and reading equations are very different activities

Another common theme was that reading the equations was distinct from reading the text. Alan stated, "I find the hardest part of reading technical writing to be the embedded numbers, equations, and variables that I often mentally skip while reading." Chris stated, "[I] make sure to take notes on the important equations," and Dan stated, "[I] write down the formulas and the words associated with them . . . go back to the beginning and try and figure out how the text tells me (how) the variables relate to each other." None of the journal entries describe a seamless activity of sequentially reading the text and equations as they appear. Rather the journals describe two distinct activities: reading the text for meaning and reading the equations in some other fashion. This difference is not surprising since an equation in very few symbols imbues meaning to each symbol, each term, and usually relies on several conceptual idealizations.

When asked in the second journal to take notes on the equations, conditions, and figures, all students responded that they had to slow down in their reading and note-taking. It simply took more effort and time to read and comprehend the equations. The students did not indicate whether they could fully extract this information; however each reported increased learning from slowing down. Interestingly, two students provided rationale for how taking more time improved their comprehension, but the other two students identified that slowing down simply increased their ability to find information when needed.

Reading and learning from example problems

Brown, et al. [5] distinguished between how people learn from examples. Rule learners extract basic concepts and governing rules from examples, whereas example learners extract what is on the surface of the example. Rule learners outperform example learners in later application of what they learned.

A few weeks into the semester the students were asked to read the example problems very carefully. Specifically, they were asked to attempt each example first and then read the author's

solution. In this way the students could contrast their approach with that of the author's. The students were also asked to take notes on overall strategies they encountered as well as unexpected single steps or mathematical techniques within an example solution that simplified the problem.

After a week of carefully reading examples, the students were asked to journal whether it helped them learn solution strategies, basic concepts, and/or both. All four students reported that they learned problem-solving steps and techniques from example problems. All four students also reported that example problems did not deepen their conceptual understanding at all. In contrast they noted that the general reading, actually working problems, and determining rationale when the author failed to state it, deepened their conceptual understanding. In terms of Brown, et. al.'s [5] distinction between rule learners and example learners, these students appeared to be example learners relative to example problems, but rule learners with other activities.

Learning problem solution strategies and not basic concepts from example problems is not surprising at all. Example problems are placed in textbooks with the intent of teaching solution strategies. However, some students focus primarily on the example problems as an instrumental means of doing homework problems. This practice, of course, places the student's learning of concepts at a disadvantage.

Changing study habits

At the end of the semester the students completed a final journal describing how reading and note-taking affected their learning. The students cited specific anecdotes and rationale, and so it appears they improved, at least temporarily, their practice of reading and note-taking. But what did they consider effective?

The students entered the class with little to no instruction in reading and note-taking. Their basic approaches were to skim the text and jot down equations and the main point. When asked what type of note-taking proved most effective, three students identified reading example problems very carefully. Reading examples was idiosyncratic though. Two students stated they made no progress at attempting the solution before reading, while another noted that attempting a solution first provided a clarifying contrast to the author's solution. One student felt that being held accountable made note-taking most effective; doing preliminary problems on the board in class motivated him to prepare.

All students stated that note-taking became ineffective when the content became too difficult, though these responses were idiosyncratic as well. Two students cited example problems that were too difficult to make progress on. One student noted that progress on difficult topics was much slower and would exceed his available time, thus rendering the note-taking less effective. Another student stated that when problems became too difficult, it would impair his self-efficacy.

All students suggested supplementing reading and note-taking with lectures on the particularly difficult topics. They did not suggest reverting the class back to a traditional lecture. Rather, they stated that they needed to learn reading and note-taking skills to become independent learners, but that topics could become too difficult to reasonably master without the lecture.

In conclusion, it appears that the structure of this class helped the students improve their reading and note-taking abilities, but that the structure would be improved if short lectures were used to cover the more difficult topics.

Suggestions for teaching reading and note-taking

The findings in this preliminary case study are limited by the number of participants, as well as the limitation of being a first study not built on a previous one. However, given these limitations, the study does suggest some reasonable perspectives on incorporating reading and note-taking into the regular learning outcomes of a technical course.

Incorporate reading and note-taking as an *instrumental* part of the course. Though reading and note-taking are valuable skills, they are tightly coupled to learning course content and solving problems. Consequently, the context for learning these skills is one in which mastery of these skills leads to mastery of course content and solving problems, and not a separate, isolated context.

Allow for reading and note-taking to be *idiosyncratic*. The literature suggests that thoughtful note-taking is individual, rather than driven by a prescribed structure. The students in this case identified individualized effective note-taking practices, which were at times opposite of other student's effective note-taking practices.

These two suggestions have implications for learning centers. Teaching reading strategies and note-taking skills coupled with course content may be more effective than teaching them as separate skills.

Supplement reading and note-taking on difficult topics. Some topics proved too difficult for students to master within the time allotted within the course. A supplemental learning resource, such as lectures, could have helped the students. Alternately, it seems reasonable to choose the topics in which reading and note-taking are the primary learning vehicle.

Finally, these findings have implications for flipped courses. Flipped courses depend upon students' abilities to read and learn from the assigned texts before coming to class. When students do not know how to effectively read disciplinary material or are unable to learn the material without additional support because it is too difficult, one of the foundations of flipped courses is eroded.

The authors wish to thank the students within this case for their commitment to learning throughout the semester.

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Appendix A: Prompts for online journals

Journal 1 prompt

Please describe the process you use to read an assignment in an engineering textbook. There is no right or wrong answer here, so answer honestly how you typically approach it. This should be a short paragraph or a numbered list. To help you understand what I'm asking, let me suggest things students may do...

...I just start at the first page and read...I have no overall plan...

...I have never read an assignment out of an engineering textbook! I just rely on lecture notes...

...I read the homework problems to solve and then carefully read only the example problems that match them...

...I preview the material first to find out how long it is and what the major topics are...

...I make notes as I go and work each example problem carefully...

...etc....

So, what is your typical approach?

Journal 2 prompt

I've asked you to take notes in your reading, but haven't been clear about what should be in your notes. So, take notes that:

1. Capture the important equations always including the conditions (such as constant acceleration) when they apply.
2. Capture simple figures to make variables (such as vectors) clear.
3. Capture when or why to use the equations.

By next Thursday post a short journal describing what you did in taking notes while reading and whether you could successfully extract the information listed in 1-3 above. Also describe whether it affected your work on problems (Did you remember more before doing problems? Did you refer to your notes instead of the book? Do you have any other observations?)

Journal 3 Prompt

For about a week you have been taking notes on example problems. Specifically I have asked you to do the following:

1. Think about how you would approach the problem as you follow the author's steps. Take special note when the author heads in a different direction than your normal inclinations. This is an opportunity to learn a new technique.
2. Note the order of the basic steps the author uses to solve the problem.

3. Note any special tricks the author uses. By tricks I mean clever short cuts that save time or calculus. (Recall the use of implicit integration when we had $y=f(x)$ and we wanted x -dot and y -dot?)

Your journal should be a short paragraph(s) that answers these questions:

1. What types of things appear in your notes about learning from examples? Give a sample or two from your notes.
2. How did taking notes about solving problems affect your actual solving problems?
3. Did the note taking deepen your understanding of the basic concepts of dynamics (ok to say "no") or did it only reinforce problem-solving steps? If it did deepen your understanding of dynamics, give an example.

Journal 4 prompt

We just finished exam 1. During the exam you undoubtedly had some moments thinking, "How do I do this problem?" These moments may have been brief; they came and left in an instant. These moments may have been really long; the problem just stumped you. With this context please thoughtfully journal a paragraph for each of these questions:

1. When you look at a problem, what is your mental strategy for recalling the steps to do the problem?
2. When you get really stumped on a problem, what is your mental strategy(ies) for finding a path to the solution?

Please reflect on these questions a bit and give thoughtful answers. Your answers will give you clues of how to more effectively read and take notes so that you learn more deeply.

Journal 5 prompt

Following journal 4, the instructor created a problem recognition and solving strategy from the aggregate thoughts in the journals. We used that strategy for our Exam 2 review.

Please post a journal that answers the following two questions:

1. How has your note taking changed over the course of the semester? Look through your notes to verify that what you say has changed has actually changed. Record even temporary changes such as, "When I was asked to take notes on example problems, I did, but then I stopped after the professor no longer focused on it."
2. How has note taking affected your ability to recognize and solve problems? Respond in both short-term and long-term effects. For example, note taking may have had a different effect on immediately solving problems versus solving problems on an exam that you hadn't looked at in a few weeks.

As possible, use examples to support your statements. This journal should be longer because it involves retracing your note taking and its effects over the 1st half of the semester.

Journal 6 (end of semester questionnaire) prompt

Question 1: Have you ever taken a technical class before this one that spent significant time discussing how to read and take notes? If so:

- a. Identify the class.
- b. Briefly describe what was taught and required.

Question 2: What reading and note taking habits did you have when you entered the class?

- a. What was your process for taking (reading) notes?
- b. What information did you jot down?
- c. How much time would you spend?

Question 3: What methods for reading and note-taking were most effective for learning the material in the text? Please cite anecdotes if possible.

Question 4: What methods for reading and note-taking were ineffective for learning the material in the text? Please cite anecdotes if possible.

Question 5: Some topics were more difficult than others. Can you describe how the topic difficulty level affected your ability to learn by reading and note-taking? For example, were there topics that were so easy, or so difficult, that note-taking did not help you learn? Please cite anecdotes as possible.

Question 6: I'd like to incorporate reading and note-taking in this course in the future. Do you have any advice for me?

Question 7: Do you think the reading and note-taking methods you practiced this semester will help you complete the rest of your engineering degree? Please cite anecdotes to explain why or why not?

Question 8: Any additional comments?

Appendix B: Class handout on note-taking after exam 1. This is a consolidation of the journal 4 student responses.

1. Identify the problem type (Goal = Know the class of problem)
 - a. Read the information carefully
 - b. Draw the diagram and label
 - c. Note givens and unknowns
2. Develop strategy for solution (Goal = Have a starting strategy deeper than a guess!)
 - a. Recall the typical method/steps for class of problem
 - b. Recall tricks associated with those methods
 - c. Use problem goal to identify strategy and equations
 - d. Identify equations based on variables and conditions
 - e. Note how equations interrelate based on variables
 - f. Solve for easy variables
3. Do the solution (Goal = Confirm the strategy or identify where it falls short)
 - a. Test the rough strategy rather than perfect it
 - b. Solve for the easy variable
 - c. Manipulate appropriate equations
 - d. Check variables while plugging and chugging
4. Unstick a stuck solution (Goal = Find a correct or complete solution strategy)
 - a. Reread, rewrite problem looking for overlooked information
 - b. Solve all variables that can be solved for
 - c. Identify what is the hurdle (variable) to overcome
 - d. Recall wide variety of other methods looking for alternate path
 - e. Work backwards for last step
 - f. Move on and come back