Using Course Workbooks as a Classroom Supplement

Dr. Nathan John Washuta P.E., The Citadel

Dr. Nathan Washuta is an Assistant Professor in the Department of Mechanical Engineering at The Citadel in Charleston, SC. He received both his B.S. and Ph.D. in Mechanical Engineering from The University of Maryland – College Park. His primary research interests include Hydrodynamics, Turbulence, and Experimental Methods.

Dr. Robert J. Rabb P.E., The Citadel

Robert Rabb is a professor and the Mechanical Engineering Program Director at The Citadel. He previously taught mechanical engineering at the United States Military Academy at West Point. He received his B.S. in Mechanical Engineering from the United States Military Academy and his M.S.E. and PhD in Mechanical Engineering from the University of Texas at Austin. His research and teaching interests are in mechatronics, regenerative power, and multidisciplinary engineering.

Dr. Emily Kate Bierman, The Citadel

Dr. Emily Bierman is an Assistant Professor in the Department of Mechanical Engineering at The Citadel. She received her B.S. in Mechanical Engineering from Purdue University, her M.B.A. from Clarke College, her M.S. in Mechanical Engineering from University of Wisconsin, and her Ph.D. in Mechanical Engineering from North Carolina State University. Her research and interests' areas include high pressure combustion, internal combustion engines, and engineering education.

Dr. Patrick Bass, The Citadel

Patrick Bass is an assistant professor in the Department of Mechanical Engineering at The Citadel, in Charleston, SC. He received his B.S. degree in aerospace engineering from Embry-Riddle Aeronautical University, Daytona Beach, FL, in 2005, his M.E. degree in space operations from the University of Colorado, Colorado Springs, CO, in 2009, and his Ph.D. in materials engineering from Auburn University, Auburn, AL, in 2016. His main areas of research interest are electroactive polymers and space mechanics.

Dr. Jason Howison, The Citadel

Jason Howison is an associate professor of mechanical engineering at The Citadel. His research areas include computational fluid dynamics, wind turbine aeroelasticity, and engineering education.

Dr. James Righter, The Citadel

James Righter is an Assistant Professor of Mechanical Engineering in the School of Engineering (SOE) at The Citadel. He earned his BS in Mechanical Engineering at the U.S. Naval Academy, his MS in Military Studies from the Marine Corps University Command and Staff College, and his PhD in Mechanical Engineering from Clemson University. His research interests include design methods, engineering leadership, collaborative design, and engineering education.

Using Course Workbooks as a Classroom Supplement

Abstract

Traditional course delivery, with daily in-class lecture and a textbook for reference, presents a number of shortcomings. In traditional lecture, students must transcribe notes from the board, which may take their focus away from the critical thinking associated with trying to understand the material. Additionally, students tend to not use textbooks as the instructor intends, but rather choose to pattern match examples to homework problems, which again limits their deeper understanding of course content. Instructor-developed workbooks have the ability to remedy some of these shortcomings, either as a replacement for or supplement to an existing course textbook.

The present paper discusses the implementation of course workbooks into a number of sophomore through senior level Mechanical and Construction Engineering courses at The Citadel. These course workbooks act as a more focused and condensed resource for students to use throughout the course. While these workbooks have no resale value, they typically cost approximately 10% of the price of a course textbook, depending on a variety of customization options and number of pages. Most students do not feel that the workbooks are a large financial burden, and they tend to use their workbooks for note taking, problem solving, and studying for exams.

These workbooks have been adopted by 6 faculty members across 8 courses and take a variety of different forms, which will be discussed in this paper. This initiative has spread organically through the department as a solution to a variety of issues regularly faced by the faculty. In some implementations, these workbooks have been helpful in reducing pre-class faculty preparation, as it eliminates the need for printing daily handouts, both for in-class exercises in a flipped class and as example problems in a traditional lecture. In other implementations, the workbooks contain lecture material so that students spend less time copying notes and more time engaging with the professor as they explain concepts. This caters to a range of different learning styles, as some students still choose to take their own notes, but more audible learners prefer to just listen and follow along in class. The workbooks have also been used to deliver supplemental problems, learning objectives, and hints for problem solving. In the present implementation, students have reported that they find the workbooks valuable, use them to study for exams, follow along with lecture more closely, and work ahead more.

Introduction

The traditional method of delivering engineering course content, through in-class lectures and a required textbook, presents a number of issues for both instructors and students. Students often spend much of their time in class simply transcribing lecture notes or figures rather than engaging in the lecture or thinking critically about the concepts being presented [1]. By asking students to multi-task, their attention is divided, resulting in poor notes or poor understanding of the concepts [2]. Instructors are often forced to slow down lecture to allow students to keep up [3] or provide lecture notes to students in the hope that students will review them as reference material outside of class [4]. This is particularly evident when solving example problems in front

of the class. Without a printed copy of the problem in front of them, students must spend far too much time copying the problem rather than solving it.

Engineering textbooks, meanwhile, present their own range of issues. They are often written as all-inclusive resources, with copious text explaining concepts students would otherwise learn in lecture [5]. While it has been shown that students who read the text perform better at problem solving [6], they tend not to engage with textbooks in this way, preferring to seek out example problems to pattern match with assigned homework problems [7]. Textbooks also tend to be written from a different perspective or for a wider range of courses than is necessary for any particular course taught by a given instructor. The lack of alignment between the content of the textbook and the particular course can lead to instructors jumping around the book, causing confusion for students.

As an in-class resource, textbooks are even less useful. Physical versions of textbooks are large, heavy, and expensive [8]. Students often avoid purchasing the textbook, hoping that they can get through the course without needing it enough to justify spending the money. Some of those that do purchase the textbook do not bring it to class, where it might be useful to learn how and when to use its reference material. A full set of several-hundred-page hardcover engineering textbooks for a semester can be far too heavy to comfortably carry around. Textbook weight has become such an issue that some states have adopted legislation to limit the maximum textbook weight allowed in primary and secondary school [9]. Rental textbooks, while cheaper, do not provide students with long-term reference material and the terms of most rentals prohibit highlighting or writing in the text. Electronic versions of textbooks are also cheaper and eliminate the need to carry heavy textbooks, but may limit students' ability to take notes alongside the text and retain many of the downsides of a traditional textbook.

Broadly, these issues of note transcribing and passive textbook usage tend to allow students to bypass the crucial process of critical thinking. By focusing on transcription and pattern matching, students never form the ability to understand concepts on a deeper level and cannot apply engineering principles in different contexts [6]. Implementing a course workbook has the ability to alleviate many of these issues.

Researchers have found success with using workbooks for various courses, using a variety of problems in the workbooks. Students found the graphical format and emphasis on visual thinking a pleasant change from the typical written format of course material [10]. Others have used their workbooks to elucidate complicated concepts and simplify electric circuit operations from the text with more understandable step by step instructions. Their workbooks included worked examples, tutorial questions, comparisons of various circuits, and summaries of course texts [11]. Other researchers have also studied the use of workbooks on different learning styles [12], [13].

These workbooks can take many forms, which vary depending on the content or format of the course or instructor preference, but they tend to be cheaper, lighter, and more distilled content when compared to textbooks. Some versions facilitate note taking and problem solving, while some provide accessible reference material that can be used easily in a classroom setting.

The present paper will discuss the adoption of a number of variations of workbooks incorporated into Mechanical Engineering courses at The Citadel, each customized to deliver different types of content to students in different courses. While some replace textbooks entirely, some are adopted alongside a textbook as supplemental material. These workbooks have no resale value, so students are able to and often encouraged to write in them, so that they act not just as passive reference material, but also as a note taking resource.

Implementation

The workbooks discussed in this paper have been developed and adopted into seven different sophomore through senior level Mechanical Engineering courses at The Citadel, taught by six different instructors. An additional Construction Engineering course on Mechanical and Electrical Systems has also adopted a course workbook. These workbooks began in a few classes and have spread organically to the current eight courses as a solution to some of the weaknesses of the traditional instructional model discussed above. These workbooks are generally made from notes developed by the instructors from their own knowledge and experience and are completely customizable and instructors are able to adjust the content semester to semester to better fit the needs of their courses.

These workbooks contain various combinations of learning objectives, reading assignments, notes (partial or complete), in-class exercises, example problems, extra out-of-class practice problems, and reference material. A table summarizing the contents of each of these workbooks is shown below in Table 1.

Table 1 – Course Workbook Summary

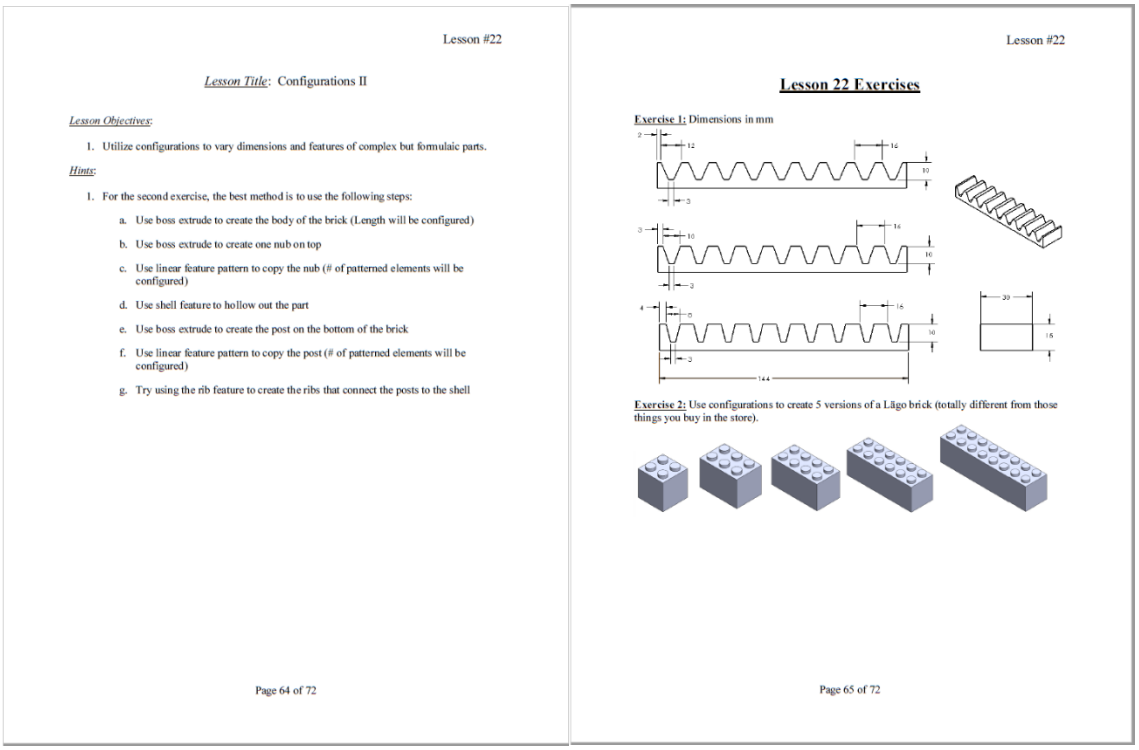
Course	Reference Material	In-class Problems	Extra Problems	Fill-In Notes	Complete Notes
Computer Applications	X	X			
Thermal Fluids I & II		X			
Controls I & II		X	X	X	
Heat Transfer		X			X
Mechatronics	X	X		X	
Construction Engineering	X	X		X	

These workbooks vary in length from 30 to 132 pages, are bound with staples along the spine or in the top left corner and are three-hole-punched. They can be printed either single or double sided, in either black and white or color, and include a thicker-stock front and back cover. Most of these workbooks utilize different colored paper for the covers to differentiate them from each other. Some instructors have chosen to split course content into multiple smaller workbooks across the semester to further reduce carrying weight and segment lecture material. Students purchase these workbooks from the campus bookstore and they have no resale value. Each course implements the workbooks in different ways with different content to fit their particular course structure or instructional style. These different implementations are discussed below.

Computer Applications Course

The Computer Applications course at The Citadel is typically taken during sophomore year and focuses on teaching students computer-aided design (CAD) using SolidWorks. Workbooks were implemented into this course for the first time in Fall 2019 and is the first in-major course in the Mechanical Engineering curriculum in which students utilize a course workbook. This course was transitioned to a flipped classroom in Fall 2016 and the requirement for a course textbook was removed in Fall 2017. Aside from the course workbook, the only required resource is a subscription to a video lecture service to provide lecture content. For these video lectures, students are assigned weekly sets of videos to watch prior to coming to class, after which they must complete a short quiz on this material. In class, lecture is typically kept to a minimum, simply reviewing the concepts from the videos, and students are given in-class exercises to complete in order to practice these concepts. The instructor walks around the classroom to check on student progress and assist with issues.

The workbook for this course includes a set of in-class exercises for every class meeting of the semester, which were previously delivered to students as handouts at the beginning of each lesson. Students are required to purchase this workbook at the beginning of the semester and they must bring it to every course meeting. In addition to in-class exercises, the workbook contains learning objectives and hints for every lesson. The learning objectives orient students to the subject matter of the day's lesson and the hints are specific pointers for common sticking points in the day's exercises. An example of what these learning objectives, hints, and exercises look like is included below in Figure 1.



Lesson #22

Lesson Title: Configurations II

Lesson Objectives:

1. Utilize configurations to vary dimensions and features of complex but formulaic parts.

Hints:

1. For the second exercise, the best method is to use the following steps:
   a. Use boss extrude to create the body of the brick (Length will be configured)
   b. Use boss extrude to create one nub on top
   c. Use linear feature pattern to copy the nub (# of patterned elements will be configured)
   d. Use shell feature to hollow out the part
   e. Use boss extrude to create the post on the bottom of the brick
   f. Use linear feature pattern to copy the post (# of patterned elements will be configured)
   g. Try using the rib feature to create the ribs that connect the posts to the shell

Page 64 of 72

Lesson #22

Lesson 22 Exercises

Exercise 1: Dimensions in mm

Exercise 2: Use configurations to create 5 versions of a Lägo brick (totally different from those things you buy in the store).

Page 65 of 72

Figure 1 – Two pages from the Computer Applications workbook

Aside from content that corresponds to each lesson, the workbook for this course also includes some reference material, such as a handout on terminology when students learn sketching and a handout on proper layout of engineering drawings. Future iterations of this workbook will likely include more reference material, such as a syllabus, directions for signing up for the flipped classroom video service, and rubrics that explain grading point deductions in greater detail.

Thermal-Fluids Course Sequence

The thermal-fluids course sequence at The Citadel is taught as Thermal-Fluids I and II rather than separate Thermodynamics and Fluid Mechanics courses. Students typically take both of these courses during their junior year of study. This course sequence is largely taught via traditional lecture, with daily example problems solved in class by the instructor to demonstrate the problem solving process. Course workbooks were implemented into this course sequence in the 2019-20 academic year. Aside from course workbooks, two additional textbooks are required for this course sequence: one focusing on fluid mechanics and one focusing on thermodynamics. The students are required to bring their workbook and one of their textbooks to class, depending on whether the day's lesson focuses on thermodynamics or fluids, the schedule for which is clearly laid out in the syllabus.

The workbooks for these courses contain all of the example problems that are solved in class for the entire semester. These problems contain the full problem statements along with any unique diagrams or reference material (tables and charts) necessary to solve the problem. For some problems, it is preferable for students to learn how to look up reference content in the textbook, as with learning to read steam tables. Because of this, students must still bring their textbook to class. These workbooks act as a valuable resource to reduce the time students spend copying problem statements in order to maximize problem solving time. Students are also able to use these problem solutions as examples for reference when solving homework problems, supplementing the way that students use their textbooks.

Controls Course Sequence

Control Systems is taught at The Citadel as a two-course sequence and students typically take both of these courses during their junior year. The content of these courses is delivered through in-class lecture with daily example problems. Workbooks were implemented into this course sequence in the 2015-16 academic year and have been improved every year since. The Controls course workbooks are the oldest and most developed set being used. The original intent was to simplify major topics of the textbook and clarify the organization of similar material into larger modules of classical control. The workbooks have evolved by making the course material more visible, material easier to find, and relevant with numerous problems for students to solve in and out of the classroom. The first course in the sequence utilizes 4 workbooks and the second course utilizes 3 workbooks, each split across the respective semesters, divided by exam periods. Two textbooks are also required for this course sequence, one focusing on Controls and one focusing on Vibrations. Daily readings from the text are assigned and these are listed in the workbook for each lesson.

The workbooks in this sequence contain learning objectives and reading assignments for each lesson, followed by lecture notes with key information removed, and then practice problems. These fill-in lecture notes provide a resource for students to replace the majority of transcription so that they can spend more of their attention in class on listening to the instructor and trying to understand the content. The students must still fill in sections of notes so that they remain actively engaged, but the burden of keeping pace with fully transcribing lecture is removed. The practice problems that follow the notes for each lesson are typically started in class, but there are more problems than can be finished in class, by design. The remainder of the problems must be completed by students as supplemental practice problems. In order to enforce this, the student workbooks are collected each exam period and the students receive a grade roughly equivalent to the percentage of these practice problems completed. An example of what these workbooks look like, including reading assignments, learning objectives, and fill-in notes is included below in Figure 2.

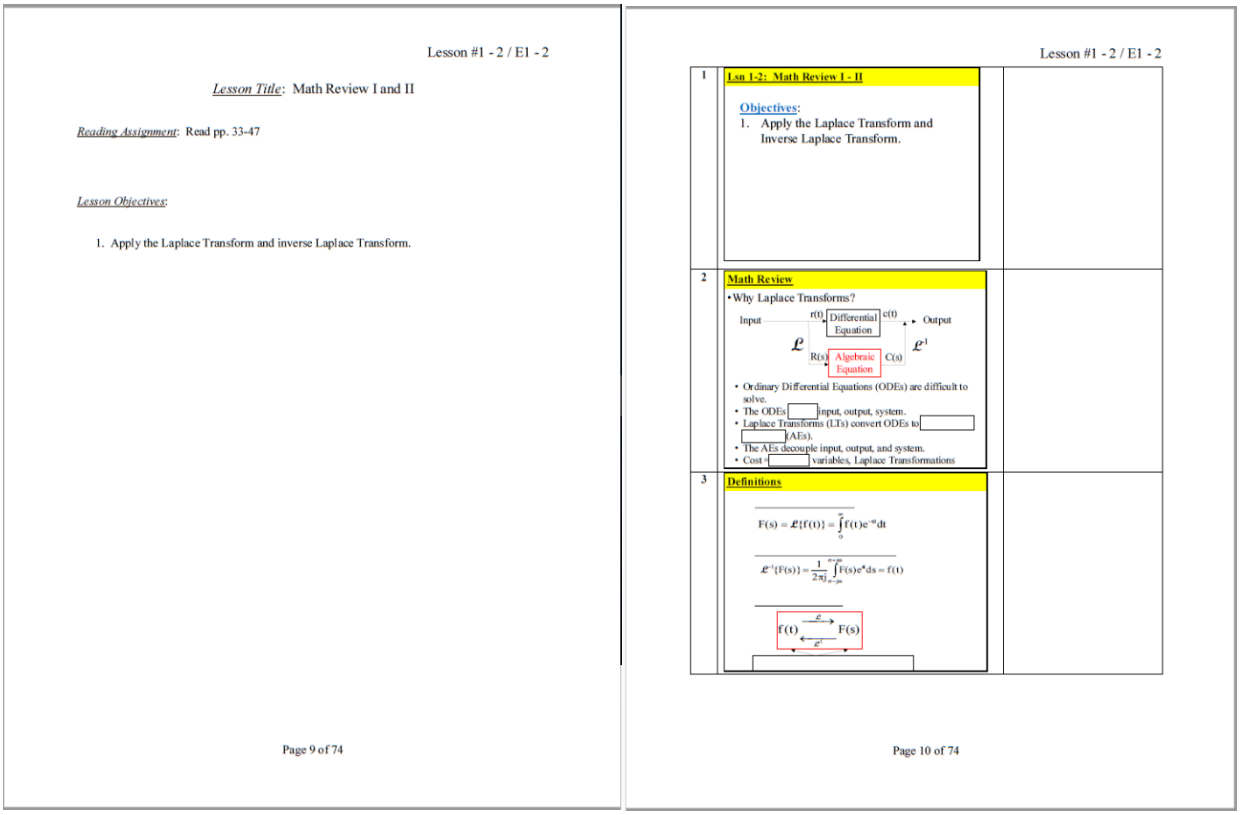


Figure 2 – Two pages from Controls workbook

Heat Transfer Course

Heat Transfer is a senior level course in Mechanical Engineering at The Citadel. The course is taught via traditional lecture with at least one in-class example problem for each lesson. A course workbook was incorporated into this course for the first time in Fall 2019 in order to reduce the note-taking burden on students. A traditional textbook is also required for this course so that students can make use of its reference material, such as thermal properties of materials.

The workbook for this course contains complete notes for every lecture throughout the semester as well as problem statements for all of the example problems. This eliminates the need for students to copy down notes while they follow along with lecture. The problem statements, as with the Thermal-Fluids course sequence, allow students to spend less time copying problems and more time solving them.

Mechatronics Course

Mechatronics is a required senior-level course in Mechanical Engineering at The Citadel. This course is taught via a mixed lecture/lab format. The lecture portion of the course incorporates frequent example problems, while the lab provides open-ended prompts for students to apply concepts learned in lecture to design a mechatronic system to solve a real-world problem of their choosing. A part of these labs is developing short programs to control sensors and actuators using an Arduino programmable microcontroller. Students generally have no background in C or C++ programming prior to this course and they are only taught programming basics in lecture, so they are expected to teach themselves how to implement more advanced programming structures.

Workbooks were first implemented in this course in Fall 2016 and the course now uses two workbooks, split across the semester. A separate textbook is also required for the course and daily readings from the text are assigned for each lesson. The workbooks contain learning objectives, reading assignments, and incomplete lecture notes for each lesson, as well as in-class example problems. The workbooks also contain copious amounts of reference material, particularly related to programming, but also instructions on how to set up the Arduino kit, data sheets for particular sensors, tables for standard resistor values, and a variety of other resources. The workbooks also include instructor-selected material for various topics, not included or covered well in the text, to include, digital logic and Karnaugh Maps.

Mechanical and Electrical Systems Course

The Mechanical and Electrical Systems course is a major requirement for Construction Engineering students and is also taken as a Technical Elective course by Mechanical Engineers. Students typically take this course during their senior year of study. The course focuses on the estimation, design, and installation of mechanical, electrical, and plumbing systems. Course content is delivered through in-class lectures, with daily example problems. Workbooks were adopted into this course for the first time in Spring 2020, with course content split into three workbooks across the semester, divided by exams so that the workbooks can be collected, graded, and returned during each exam period. A separate textbook is also required.

These workbooks consist of learning objectives and reading assignments listed for each lesson, as well as incomplete notes, and problem statements for in-class example problems. The workbooks also contain a significant amount of reference material, such as thermal properties of common building materials, fan performance curves, and electrical wiring standards. Students are responsible for completing any example problems that are not completed in class, which is enforced by collecting, grading, and returning workbooks for completeness during each exam period.

Results & Discussion

While these workbooks have all been implemented in different ways to fit the needs of the different instructors and courses, they have all been successful in supplementing the existing instructional methods. For the students, these new resources have not added significantly to the cost of their required resources across these courses. Across all eight courses, the cost of the workbooks totals $191.55, an average of $23.94 per course, while the cost of new copies of the other required resources from the campus bookstore totals $1692.10, or $211.51 per course. This workbook total comes to just 10.2% of the total amount spent on required resources.

In order to solicit student feedback on the workbooks, surveys were distributed to 57 students in the Computer Applications course and 67 students in the Controls course sequence. In the Computer Applications course, where the workbook costs $12.65, 73.7% of students responded “Disagree” or “Strongly Disagree” (D/SD) to the statement “The cost of the workbook was a significant financial burden.” Similarly, of students surveyed in the Controls course sequence, 74.6% responded D/SD to the same statement, despite the relatively higher cost of the workbooks at a combined $66.20. Only 11.9% of those same students responded D/SD to the statement “The cost of the textbook was a significant financial burden.” With the long term potential to replace textbooks, these workbooks have proven to present a smaller financial burden on students.

The workbooks have also proven lighter than their textbook counterparts. On average, the workbooks weigh 0.45 lbs each, compared to the average textbook for these courses, which weigh 3.69 lbs on average. This means that the workbooks weigh on average 12% of what a textbook weighs. This makes it significantly easier for students to bring their workbooks to class to use as intended. Prior to workbook implementation in the Thermal-Fluids sequence, periodic textbook checks were performed in class to ensure that students brought their textbooks to class. In Spring 2019, only 52.1% of students brought some version of their required textbook to class on the 6 days that textbook checks were performed. Only 59.7% of students in Controls reported buying the textbooks, while 95.5% of those surveyed purchased the workbooks. While no data has been collected in this class on the number of students that bring workbooks to class, instructors report that most students regularly bring their workbooks to class and use them when completing example problems.

In addition to a purely financial or physical perspective, students surveyed were also able to appreciate the value that these workbooks provide. In addition, 86% of Computer Applications students responded “Agree” or “Strongly Agree” (A/SA) that the workbook was a valuable resource. While 72.7% of Controls students responded A/SA to the same statement, only 31.3% of the same students responded A/SA to the statement that the textbook was a valuable resource. Using workbooks as an in-class resource that is incorporated into lecture provides students with a tangible benefit that they feel is worth their time and money.

One of the primary benefits of these workbooks is their ability to keep students actively engaged while in lecture. By utilizing fill-in notes and example problems, 52.2% of Controls students responded A/SA to the statement “I paid more attention in class because of the course

workbook," while 61.2% responded A/SA to the statement "I was able to complete more in-class example problems because of the workbook." This points to the idea that students not only purchase the workbook and bring it to class, but also use it as intended.

In order to enforce workbook usage, the workbooks are collected during each exam period in the Controls course sequence and students are given a grade roughly equivalent to their completion percentage of practice problems. Completion of notes are not graded in the event that students choose to take notes separate from the workbook, but students are responsible for completing all in- and out-of-class problems. The average score on these workbook checks for the first course in the sequence from 163 students that took the course in Fall 2018 and Fall 2019 was 93.4%. The average score in the second course in the sequence from Spring 2019 was 95.5%. Both of these numbers point to strong adherence to completing the workbook example problems. By grading workbooks, it is easier to enforce the requirement that students own and use them as intended.

While students have a lighter workload in class due to not having to transcribe as much material, these workbooks also reduce the day-to-day workload on instructors during the semester. All of these workbooks in some way eliminate the need to print the majority of handouts, either from in-class exercises or example problems or from reference material. In addition to printing, these workbooks also reduce in-semester lesson prep. By definition, these workbooks need to be prepared before the semester so that they can be printed, which forces lessons to be set earlier and the notes to be developed sooner. While this presents the disadvantage of requiring work to be completed before the semester, it also greatly reduces the day-to-day deadlines for course preparation during the semester. This method of content delivery could also aid in the transition from in-person to online course delivery. Having a single structured resource that can include learning objectives, reading assignments, notes, and practice problems provides a uniquely suited required resource for a course, whether it is delivered in person or not. Additionally, as faculty transition out of academia and new faculty fill positions, the workbooks help new instructors prepare their courses. In a small school where a faculty member teaches different courses each semester, the workbooks assist faculty who are willing to adopt them. In courses where there are multiple instructors, the workbooks help standardize lesson content.

Outside of class, these workbooks have also proven beneficial to students, in terms of providing more practice problems to complete and a resource to use when preparing for class. When surveyed, 61.2% of Controls students responded A/SA to the statement "I worked through more out-of-class practice problems because of the workbook." While this was certainly influenced by the workbook grading policy referenced above, these extra problems graded on completion are a low-effort method of increasing student practice with problem solving.

Workbooks have also impacted course preparation, as 34.3% of students in Controls reported using the workbook to work ahead and prepare for class, compared to just 4.5% of students that used the textbook in the same way. By comparison, students in Computer Applications were asked to respond to the statement, "The workbook allowed me to work ahead in class," and 68.4% of students responded A/SA to the statement. For many students, receiving

all of the in-class problems for the entire semester presented an opportunity to work ahead of the class, so that they were able to get them done early and start working on homework while still in class. 85.9% of students in this course also reported preferring using a workbook to receiving these exercises as handouts at the beginning of class, presumably in part because of this ability to work ahead.

Workbooks have also been beneficial to students in completing homework problems and studying for exams. In student free response comments on the distributed surveys, numerous students indicated that the workbooks were helpful with homework and exam preparation. Similar comments are present in end-of-semester course evaluations. One student argued that the workbooks "put the example problems right next to the reference material." This coupling of notes and example problems removes the step between homework problem confusion and finding relevant reference material. Without the workbook, students need to search through the large volume of text and ancillary material provided in the textbook, which may not be presented in the same method or same order as course notes.

In addition to using workbooks as a resource to help with homework problems, students also tend to use them as an aid in studying for exams. A survey is handed out during each exam period in the Controls course sequence to determine what resources students utilize in studying for their exams. Table 2 shows the results of one of these surveys. On average, students reported using their workbooks as the primary reference for study material, making up 44.7% of their total study time. By comparison, course textbooks accounted for just 4.9% of overall study time for these students.

Table 2 – Controls Course Self-Reported Study Methods

Study Method	**Minutes**	**Percent**
Course Text	16	4.9%
Instructor	15	4.5%
Old Tests, HWs	88	26.0%
Workbook	151	44.7%
Study Groups	52	15.5%
Other	15	4.4%

In addition to being heavily used as an exam study resource, the workbooks also prove to be beneficial to the students who use them more. Figure 3 shows the same study time survey results discussed in Table 2, but broken down by the final grades students received in the course. This plot shows that students who received A's and B's spent a greater proportion of their study time using the workbook and less of their time using old exams and homework assignments when compared to students who did not perform as well in the course. One student survey free response comment emphasized that the workbooks "maximize your time spent with relevant material." This reinforces the idea that the workbooks present a more distilled version of course content than the textbook, which is especially important when deciding how best to maximize the impact of available study time.

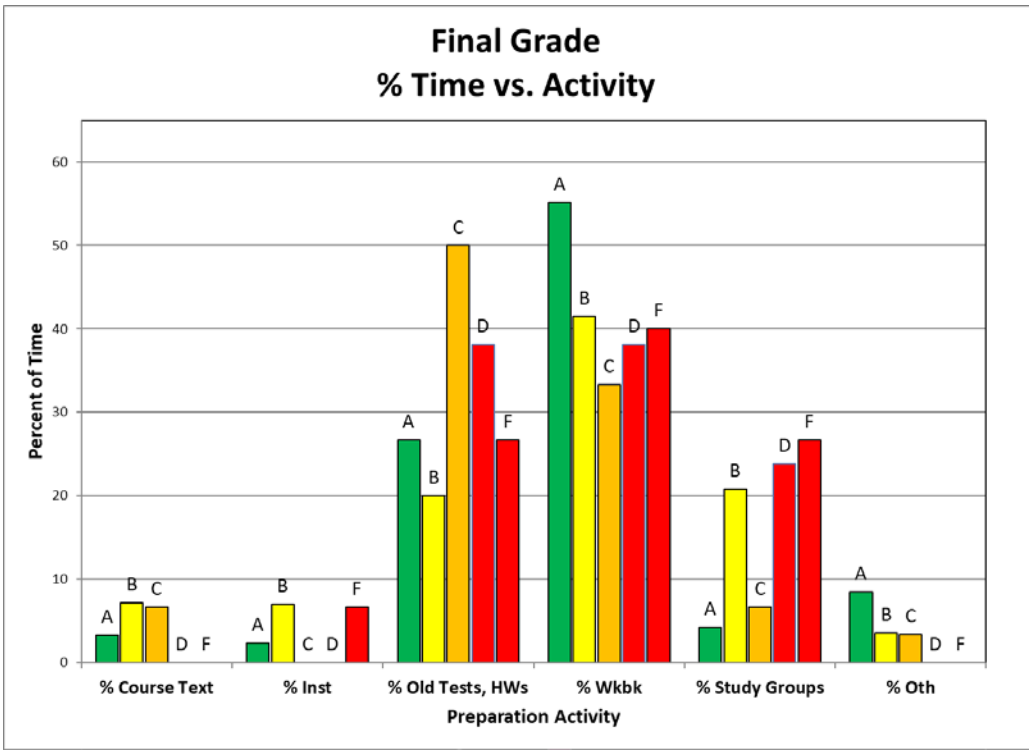


Figure 3 – Controls student exam

While many students view course notes in the workbook as a helpful resource, both for following along in class and when reviewing for an exam, some students have criticized the fill-in note format. In end-of-semester course evaluation responses, students tended to criticize typographical and formatting errors that caused confusion in the fill-in notes. Some also expressed a preference for writing their own notes by hand. One student wrote a constructive suggestion to, “Leave more blanks in the workbook so students have to actively write notes instead of filling in blanks.” Another student provided feedback to, “Give us a complete booklet with all the stuff filled in already. I hate having gaps in information and relying on other students to ask what’s supposed to be there.” Both responses suggest a dissatisfaction with the fill-in note format, but with different solutions. While not provided notes keeps students more actively engaged, there is also a greater burden of keeping up with lecture. Conversely, complete notes provides students with good reference material without transcribing the lecture, but eliminates active engagement from note taking. Each approach has tradeoffs, and all three approaches are present in the courses discussed in this paper.

In courses where notes are not included in the workbook, many of the other content areas discussed above can still be included to complement the existing instruction. Students in the Computer Applications course were asked if they found the learning objectives and hints in their workbook useful and 84.2% responded A/SA. In contrast to this, in course evaluations for the Thermal-Fluids course sequence noted that the workbook had “limited long term value because the example problems lack context.” Including learning objectives alongside example problems has the ability to orient students to the material and give them a hint about what concepts they

should be using in problem solving. In free response comments on the Computer Applications surveys, students gave a number of suggestions for improvements to the workbook. These responses seemed to fall into a number of major categories that each received numerous suggestions. First of all, students requested more reference material, including directions on signing up for the flipped classroom video service and walkthroughs of concepts in some of the earlier or more difficult lessons. The second major category was extra practice problems. While students were able to complete in-class exercises for practice, many expressed the desire to attempt extra practice problems either to better understand complex topics or as an opportunity for extra credit. The third category of comments expressed a desire for the in-class exercises to relate to the videos or lecture content. This category relates to the reading assignments listed in the Controls, Mechatronics, and Construction Engineering courses. By relating workbook content to the text or lecture videos, students have the ability to cross-reference that material and improve on concepts that they struggle with.

Practical Considerations

While many of the concepts discussed herein are not completely novel, the combination of benefits represented by these workbooks can act as a valuable course supplement. While textbooks do serve a purpose, as reference material with detailed discussions of concepts, workbooks fill the need for an in-class resource that textbooks are increasingly unable to fulfill. In developing these workbooks, the authors have identified a number of best practices for adapting and implementing course material for a workbook. As with any set of course materials, workbooks are most easily implemented into already-developed courses. Because the books must be proofed and physically printed, workbook content must be finalized prior to the semester, typically on the order of a month prior to the start of classes. While it is certainly possible for a newly-developed course to meet this deadline, as is the case with the Mechanical and Electrical Systems course discussed above, it is more difficult to complete all first-time course preparation for the semester in advance of classes. Because of the more rigid structure of the workbook, this could also limit the flexibility of the course that may be necessary for the first time through.

For an already developed course, adapting content to a workbook can be a fairly straightforward process. Board notes or PowerPoint slides are already likely formatted in a logical manner than can be directly transferred to a workbook. In PowerPoint, this is quickly accomplished by exporting the slides as handouts, using the “Notes next to slides” option. This produces the two-column format shown on the second page of Figure 2 shown above, with the slides in the left column and room for note-taking in the right column. Some slight slide resizing may be required, but three slides per workbook page tends to give a reasonable text size. Adapting in-class exercises can be an even simpler process, as documents previously used for handouts can simply be copied and pasted into a single document, with page breaks included between lessons.

When developing content for the workbook, issues of copyright should be considered. Wholesale reproduction of copyrighted content in this context is prohibited under United States copyright law, so an effort should be made to utilize as much original content as possible. In order for the workbook author to judge whether they have infringed on copyright, there are a

number of distinctions that should be considered. The first of these is the idea-expression dichotomy, most clearly described by the quote, “Unlike a patent, a copyright gives no exclusive right to the art disclosed; protection is given only to the expression of the idea – not the idea itself. [14]” While the particular form of copyrighted content is protected, the underlying ideas and facts are not subject to copyright. The second consideration is fair use, which outlines 4 considerations used to determine when use of copyrighted materials does not infringe on the copyright, outlined in the following quote:

> In determining whether the use made of a work in any particular case is a fair use the factors to be considered shall include—
> (1) the purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes;
> (2) the nature of the copyrighted work;
> (3) the amount and substantiality of the portion used in relation to the copyrighted work as a whole; and
> (4) the effect of the use upon the potential market for or value of the copyrighted work. [15]

Therefore, use of copyrighted material is allowed under fair use if it is for nonprofit educational purposes, constitutes factual information, is used in limited amounts, and does not directly replace sale of the copyrighted work. Instructors should consult with their school librarians for a more thorough investigation of these ideas.

The consideration of a single workbook versus multiple workbooks depends on the structure of the workbook and the course. While a single workbook minimizes any possible confusion, the biggest consideration should be the overall size and thickness of the book. With too many pages, issues with the workbook start to resemble the issues of a textbook, namely that it is too heavy and bulky for students to reliably bring it to class. A good rule of thumb is to keep the workbook under 100 sheets of paper (100 pages single-sided or 200 pages double-sided). Breaking course content into multiple workbooks can be helpful, especially if the course can be clearly delineated into discrete topics or sections, with workbook transition occurring at exam periods. Again, the downside to this approach could be that it introduces an element of uncertainty, especially around the transition period, when some students will accidentally continue bringing the old workbook.

In future implementations, these workbooks will continue to be iterated and improved upon. The authors hope to determine if particular types of workbook content are more useful than others across all styles of course delivery or if particular modules are better suited for different courses. Workbooks are also being explored for a wider array of courses, from Technical Writing to Senior Design, to determine if the benefits described above can be achieved in different course styles.

Conclusions and Future Work

This paper discusses a survey of various course workbooks in a mechanical engineering program. Several instructors have adopted their own workbooks to supplement course textbooks

with various resources collected in them. Overall, student perception of the workbooks is fairly positive with most using them significantly more than their textbook. They favor the cost savings and having the important lesson materials in a concise format, saving them time searching through the textbook for salient points. Faculty have found that the workbooks provide useful for lesson preparation, transition of instructional material to and from other faculty, and as a way to standardize some content when multiple instructors teach a course. However, the faculty member must be deliberate about the workbook development and organization before the semester begins. This requires a well-organized schedule and insight to the material rather than building the course as one teaches it during the semester.

Bibliography

[1] S. M. Reynolds and R. N. Tackie, "A Novel Approach to Skeleton-Note Instruction in Large Engineering Courses: Unified and Concise Handouts that are Fun and Colorful," in *2016 ASEE Annual Conference & Exposition*, New Orleans, LA, 2016.

[2] S. T. Peverly, J. K. Garner and P. C. Vekaria, "Both handwriting speed and selective attention are important to lecture note-taking," *Reading and Writing,* vol. 27, pp. 1-30, 2014.

[3] S. L. Robinson, H. E. Sterling, C. H. Skinner and D. H. Robinson, "Effects of Lecture Rate on Students' Comprehension and Ratings of Topic Importance," *Contemporary Educational Psychology*, vol. 22, pp. 260-267, 1997.

[4] J. van der Meer, "Students' note-taking challenges in the twenty-first century: considerations for teachers and academic staff develpopers," *Teaching in Higher Education*, vol. 17, no. 1, pp. 13-23, 2012.

[5] R. E. Mayer, W. Bove, A. Bryman, R. Mars and L. Tapangco, "When Less Is More: Meaningful Learning From Visual and Verbal Summaries of Science Textbook Lessons," *Journal of Educational Psychology,* vol. 88, no. 1, pp. 64-73, 1996.

[6] C. J. Atman and K. M. Bursic, "Teaching Engineering Design: Can Reading a Textbook Make a Difference?," *Research in Engineering Design,* vol. 8, pp. 240-250, 1996.

[7] C. S. Lee, N. J. McNeill, E. P. Douglas, M. E. Koro-Ljungberg and D. J. Therriault, "Indispensable Resource? A Phenomenological Study of Textbook Use in Engineering Problem Solving," *Journal of Engineering Education*, vol. 102, no. 2, pp. 269-288, 2013.

[8] S. M. Samuel, N. H. Nicholls, L. N. Lalwani, D. S. Carter and P. F. Grochowski, "Students, Vendor Platforms, and E-textbooks: Using E-books as E-textbooks," in *2013 ASEE Annual Conference & Exposition*, Atlanta, GA, 2013.

[9] T. Adams, S. Rios and K. McDonald, "Textbook Weight in California: Data and Analysis," California Department of Education, 2004.

[10] A. Post and T. Narayan, "A Design for Manufacturability Workbook," in *2006 ASEE Annual Conference & Exposition*, Chicago, IL, 2006.

[11] Y.-C. Wong, "An Effective Integrated Approach For The Teaching Of Power Electronics To Part Time Engineering Students," in *1998 ASEE Annual Conference & Exposition*, Seattle, WA, 1998.

[12] Y. Demirel, "Effective Teaching And Active Learning Of Engineering Courses With Workbook Strategy," in *2004 ASEE Annual Conference & Exposition*, Salt Lake City, UT, 2004.

[13] P. McCright and J. Larsen, "Coordinating Learning And Teaching Styles In Undergraduate Engineering Economy," in *2004 ASEE Annual Conference & Exposition*, Salt Lake City, UT, 2004.

[14] *Mazer v. Stein*, 1953.

[15] *Limitations on Exclusive Rights: Fair Use. 17 U.S.C § 107*, 2010.