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Abstract

This paper outlines a study conducted on the efficacy of course-provided reference sheets on student learning when allowing reference material during exams. In ME388 Helicopter Aeronautics, at the United States Military Academy, a four-year undergraduate institution, a reduction in course exam failures occurred after changing from student provided note sheets to course provided note sheets during exams. In previous iterations of ME388 Helicopter Aeronautics exam resources varied from student-provided note sheets to open-book exams with several iterations taking some combination of the two. Another course in the department of Civil and Mechanical Engineering at the United States Military Academy, MC311 Thermal-Fluid Systems I, inspired this research with its long-standing success with a course-provided 8½ x 11" front-and-back equation reference card used for over 20 iterations with positive results, affectionately named and referred to as the RDC for Reference Data Card, although it contains almost entirely equations, not data. Thus, the ME388 course instructors piloted a two-page course-provided equation sheet to students taking ME388 Helicopter Aeronautics at the beginning of the spring semester in the 2020 Academic Year with the goal of simplifying the teaching model and attempting to help students avoid common mistakes made during previous iterations of the course that used various formats of closed- and open-book exams. This paper will introduce the concept of closed- and open-reference teaching and assessment methods including a canvas of academic literature on related research. Motivation for the inclusion of the course-provided equation reference sheet determined from course feedback collected from previous iterations is analyzed and discussed. Current students were surveyed to gain insight into the students' comfort with the material and gain anecdotal results on the method. Next, the aspects of designing and implementing the reference material are discussed with thoughts on layout, which equations to include, which data to include, and how to incorporate the reference material into daily instruction. Student feedback was analyzed along with discussion on any adjustments made thereafter along with applicable justification from student feedback. Finally, a conclusive evaluation was determined from a synthesis of anecdotal evidence, Likert scale feedback, and exam grade comparison to previous iterations. This was weighed against the literature from other academic research and includes a discussion of the merits and disadvantages of allowing reference material on exams. The paper concludes with a final determination on the pilot program's efficacy on student learning when implementing a course-provided equation reference sheet and recommendations for future work.

Keywords: course-provided reference sheet, equation-sheet, note-sheet, cheat-sheet, examination, open-book, closed-book, engineering education, helicopter aeronautics

Introduction

The engineering discipline is rife with reference material both as a profession and throughout its education at all levels. The question on how much, if any, references to allow during examination remains open. Merits and disadvantages are argued and demonstrated on both sides of the argument. To study the question, the engineering classroom was used as a laboratory for asking how course-provided equation reference sheets would affect student learning. This study took place at the United States Military Academy, a four-year liberal arts college located in West Point, NY in spring 2020. 31 students were enrolled in two sections of the spring-semester only engineering course titled Helicopter Aeronautics. The course covered the aerodynamics of helicopter flight as analyzed in hovering, translating, and partial powered flight. Theory and experimental results are used to predict aircraft performance. The course analyzes the dynamic response of the rotor system and the performance aspects of the vehicle as a whole. This is followed by a design workshop, during which students complete the initial sizing of a helicopter to meet specific mission requirements. The course includes one flight lab in a helicopter, a laboratory examining rotor power and thrust utilizing a whirl stand apparatus, and one field trip to a commercial helicopter company. The total meeting time is 28 lessons at 75 minutes and 2 labs at 120 minutes each. The textbook used by both sections was *Principles of Helicopter Aerodynamics* Second Edition by J. Gordon Leishman. The same instructor taught both sections in 2019 and 2020. The classes met up to three times per week, but mostly twice per week. The first section met from 0730-0845 and the second section met from 1445-1600 in the same room. Attendance was required in by both sections.

The spring version of the course in 2019 allowed students to make their own note sheets in which they were expected to write-down or memorize any or all applicable equations they may need. General feedback was that some students did not have the knowledge or did not write down one or more applicable equations required for certain exam questions. To alleviate the issue, based on instructor experience teaching other engineering courses in the department, this pilot study conducted in the 2020 iteration of Helicopter Aeronautics would offer a new "Reference Data Card" approach as was successful in other courses. The course iteration from 2019 to 2020 does not change in content, presentation, format, textbook, classroom, or instructor. This study aims to compare the previous grades earned with the earlier version with student-provided note sheets to those of the pilot program in 2020 with a double-sided 8½ x 11" course-provided equation sheet (RDC). Moving from student-provided note sheets to course-provided note sheets correlates to a course final exam failure rate reduction from 11.8% to 0%.

Related Work

The efficacy of providing reference materials for exams is not conclusively settled. References can take several formats and are viewed by a variety of researchers as beneficial to student learning and as detrimental by others. Various means exist in contrast to a traditional closed-book exam without any references. A comprehensive but not all-inclusive list includes the following (or variations on the following): open-book exams, exams with student-provided note sheets, exams with course-provided note sheets, and "open everything" exams. This study focuses on the course-provided note sheet as a means of instruction and for use during examination.

Open Book References

An open book examination allows students to use the entire course textbook as a reference during an exam. Open book examinations are a popular method among disciplines with dense material that is generally not expected to be memorized. In an experimental evaluation of open book examinations, Kalish [1] found that average scores were not affected when comparing open book and closed book examinations and concluded that open-book examinations may benefit some students more than others. These findings were echoed by Bacon [2]. According to Feldhusen [3], students prepare less for an open-book examination, which may ultimately decrease their overall learning. The general argument for student preparation versus realistic expectations for what should be memorized consistently appears as a common theme laid out in many of the arguments from previous research.

Raadt and Kalish found that students who prepare adequately for the open book exam generally do better than those who get a false sense of comfort provided by having the book available on the exam. They argue that students tend to be caught without enough time due to lack of preparation or spend far too long looking for material in the textbook. Their main counter-argument for the use of open-book examinations was the "degradation of the seriousness of examinations that can lead to superficial learning," stating that "[r]ather than benefitting students, allowing students to have access to textbooks or teacher-prepared notes can be a hindrance" [4,1]. To specifically address the question over time spent on an exam referencing the material in the textbook, Boniface "compared the time spent referring to open-book materials and their results." His main conclusion was that "students who spend more time than others referring to such materials tend to end up with poorer marks." Boniface found that those students that spent more time referencing the textbook tended "to be students who have performed poorly on prior assessment items that rely more on these materials during an examination" [4, 5]. Boniface's results revealed that, "of the 30 candidates observed, those who devoted more examination time to using notes and texts obtained less good scores and had obtained low scores on previous assessments" [5]. Raadt concludes that "open-book examinations can have benefits, such as reduced anxiety, de-emphasis of memorization and reduced cheating," but that they "can also have disadvantages such as reduced preparation and the need for time during examinations to look up facts." Thus, as Raadt also suggests, an "emerging alternative allows students to bring a 'cheat-sheet' of hand-written notes" [4]. Consequently, open-book examinations are generally good for "good" students and not as helpful for those performing below average in the course. A potential solution to address these concerns is an increasingly popular method allowing student-provided reference (note) sheets.

Student-provided Reference (Note) Sheets

The student-provided note sheet, colloquially referred to as a "cheat sheet," or "crib sheet," allows the student to create his or her own reference for an exam rather than use the entire course textbook. Erbe suggests that student created note sheets can "reduce examination anxiety while increasing learning, particularly in courses that assess on the first three levels of Bloom's taxonomy" [6, 7]. Raadt found statistical significance that "[s]tudents with cheat-sheets performed, on average, higher" and "students without cheat-sheets performed worse" to indicate "that the preparation and use of student created cheat-sheets does have an impact on student performance" [4]. Researchers make various arguments against student-generated note sheets, including Rehfuss who is concerned "that pre-supplied note sheets detract from conceptual thinking and discourage studying." To address Rehfuss' concern, Cone advocates for student-generated cheat sheets stating that "students, in generating their sheets, are forced to study and figure out which concepts are the most important for review" [8-10].

To explore the benefits of the student-provided note sheet over an open-book exam, Hamed [11] examined "first whether students' performance in physics exams would vary significantly depending on whether they were allowed to use the textbook or a student-generated 'cheat sheet.'" To ensure a baseline comparison, Hamed compared the performances of two groups on the same tasks under the same conditions, observing that, "on the whole, there were no statistically significant differences," which "implies in itself that the two groups had similar intrinsic skills" [11]. During his research, Hamed found that although "the majority of the students continued to prefer having the textbook available while taking the exams," that "the students' performance on the exams improved when they moved from using the text to using the sheet." He hypothesizes that by having to create their own note sheet that it "may have forced them to spend more time studying prior to the exam rather than relying on having the text," and that it "may also have forced them to organize their thoughts and the concepts a little better while selecting what to put on the sheet." By organizing their concepts, Hamed further explains that students are forced to "identify what was worth taking to the exam and what was 'just a detail.'" Hamed interestingly found that the majority of the "A" students "preferred using the sheet" while the majority of the "C" and below students "preferred having the security of the whole text during the exam" [11]. Hamed found that "a survey of the 44 students" conducted two weeks after a physics exam, "revealed that 25 preferred having the text with exams, 17 liked sheets, and two were undecided." Hamed notes that underlying these preferences that "the majority of students receiving an A grade preferred the sheet, and the majority of students receiving a C and below preferred the text," while students "receiving a B were split equally between the two choices, and the two undecided students were in the B group." Notably of those students in the research that preferred the textbook reported the reason as having access to a "greater amount of information" and "its potential aid with conceptual questions and with similar exam problems." The students who preferred the text reportedly justified their preference by reasoning that the "possession of the text eliminated student troubles in creating a sheet in which a potential advantage lay with the more capable students" [11]. Hamed states that "[c]onversely, students who preferred the sheet were confident in their ability to select and organize, making relevant material easier to find" [11]. Interestingly, Hamed found that students feared a correlation of exam difficulty to the level of material allowed as a reference, stating that the same students who earned good marks and preferred the note sheet "were also concerned that possession of the text might be offset by more difficult exam questions" [11].

Raadt made a more in-depth examination of the advantages and disadvantages of student-created note sheets. Raadt's study revealed "that students who create and use cheat-sheets performed better, on average, in an introductory programming examination." To explore deeper, though, Raadt was interested in what students put on their reference sheet and how it correlated to their performance, finding that "[c]ertain features of cheat-sheets were found to be related to superior performance, which may relate to student understanding" [4]. This raised the question of optimal material and layouts for note sheets, in general. In preparing their note sheets, Raadt found that it "proved to be sufficient for learning what was on the test." He provides anecdotally that students "tailored the information to their own needs and wrote down information they still needed to learn," stating further that the "act of writing and organizing the information for the cheat sheet allowed most students to fill in the holes in their knowledge" Raadt observed that by "ordering cheat-sheet content to match course content" students earned a "higher examination performance." He hypothesized that "students who create cheat-sheets in such an ordered fashion are undertaking a more thorough, start-to-finish approach when creating their sheets, and perhaps learning more from this experience." He also hypothesized that it "may also be the case that when content was ordered in a way that was familiar to the students' experience, less effort was required to find information on the cheat-sheet during the examination" [4]. Visco et al. [12] explored the diversity in the quality and composition of student created cheat-sheets by analyzing the student created note sheets for a chemical engineering examination. In their research, however, despite the "great variety among students' cheat-sheets," that "the 'goodness' of a cheat-sheet does not necessarily map to examination performance" [4, 12]. An important observation was against the inclusion of example problems on reference sheets, with the "inclusion of sample examination answers in cheat-sheets" being "related to poorer performance," potentially revealing "a poorer understanding of concepts by students" [4]. Another option, seemingly in between the open book reference exam and student-provided references is the course-provided reference sheet.

Course-provided Reference Sheets

A course-provided reference sheet includes some of the material from the textbook and/or the lecture material to include relevant equations, constants, details, figures, variables, definitions, charts, or information. The course-provided reference sheet comes by many names. Caplan-Auerbach refers to them as "Equation Dictionaries" [13], Rehfuss as "Formula Sheets (FSs)" [8], McCaskey as "pre-population of student exam note sheets" [9], and many courses at the United States Military Academy as "Reference Data Cards" (RDCs). McCaskey [9] sought to determine the efficacy of course-provided reference sheets by relating their employment to student preparation, asking if the "pre-population of student exam note sheets with formulas could be one of a number of factors that affect student exam preparation." McCaskey hypothesized that a course-provided note sheet allowed students greater time to "focus their exam preparation on more conceptual aspects of the course" [9]. In comparing students over two iterations, one where the students provided their own note sheets and another where McCaskey provided the equation sheet and allowed students to fill out notes around the blank half of the sheet, he found students with the course-provided sheet tended to focus more on equations over conceptual ideas. He provides two examples of students commenting on not knowing "which equation to apply." McCaskey surmises that one "plausible explanation for the difference in behavior between the two groups is that a pre-populated equation sheet frames equations as the most essential part of the course while deemphasizing their potential as meaningful expressions of conceptual ideas" [9]. McCaskey concludes that his approach "framed equations as centrally important to the [exam] and discouraged them from adding other important conceptual material" [9].

McCaskey is not alone in the concern over the loss of meaningfulness by taking away the need for students to provide the equation themselves. Rehfuss argues a similar hypothesis to McCaskey stating that the students do not fully understand or appreciate the relevant parameters of an equation if it is given to them rather than internalized [8]. He is concerned that with a course-provided reference sheet, the "student develops no perspective about the relative importance of different parts of an equation, constants being indistinguishable from variables if one is accustomed simply to plugging in numbers" [8]. Rehfuss makes several arguments against the use of course-provided equation reference sheets to include that their use (1) "ignores that the mind needs internalized knowledge with which to reason," (2) "implies that math is more important than [the subject at hand]," (3) "encourages an encyclopedic survey course lacking depth," (4) "detracts from conceptual thinking," (5) "obstructs understanding […] complex phenomena," and (6) "discourages studying" [8]. In justifying his argument, Rehfuss states that the formula sheet "advocate may tend to 'cover' too much material, feeling that the students have more available time, freed of recall-stress." However, this seems in line with the Erbe's goal [6] to reduce recall-stress. Rehfuss goes on to explain that in general "Physics texts are massive encyclopedic tomes" that challenge instructors to cover more and more material by reducing recall load on students. The formula sheet thus allows the instructor's conscience to be clear to cover more material than can readily be internalized. Rehfuss suggests that it may be better to reduce the number of items discussed in a course in favor of gaining a "deeper understanding of fewer topics" [8]. Rehfuss is also concerned with, as others were with open-book references and student-provided note sheets, how the course-provided "formula sheet (FS)" may discourage studying: "Knowing that an exam comes with an FS, the beginning student may reason 'physics apparently is a bunch of equations, which they supply' so why study?" [8]. He is concerned that the employment of a course-provided reference sheet in fact "delays developing expertise" in the related STEM field, stating "[t]hough not really expected to become an instant expert, the beginning student should be spared the false impression that scientific literacy can be attained by holding the laws of physics at arm's length on a piece of paper" [8]. Both Rehfuss and McCaskey reference Haskell [14] in explaining the relationship between potential reduced learning and the goal of expertise in a given field. Haskell states that "true expertise in any field includes an instantly accessible mental base of interconnected facts that Chi calls 'a rich structure of domain-specific knowledge'" [8,14,15]. Haskell further states that "experts […] are differentiated from novices not by their strategies but by their rich stores of knowledge," and that "[c]ompetent problem solvers (experts) not only have an appropriate knowledge base available in their long-term memory, they also have the ability to access and use that knowledge" [9,15] The research seems to suggest a trade-off or some balance that exists between memorization, course-provided references, and the goal of expertise.

However, the argument against using course-provided references seems to go at odds with what students will experience in engineering practice once they graduate. As Raadt acknowledges, "[w]hile expert programmers possess a wealth of tacit solutions to problems (Soloway, 1986), they are not expected to memorize specific information, so it is unrealistic to expect students to do so for an examination" [4]. However, engineers are also not generally expected to write their own reference manuals, so student-provided note sheet pedagogy seems to fail this test as practical to the eventual application of material in professional practice. Engineers are however expected to be able to reference provided manuals, charts, and data tables signaling a potential middle ground to be explored.

"Open-everything"

The "open-everything" approach is an attempt at translating real-world engineering practice to the learning environment where real-world engineers are expected to be able to reference vast sources of information and equations from volumes of manuals and databases. The approach essentially allows as a reference exactly what the name implies, everything short of collaboration. In this approach one question becomes, what must readily be recalled from long-term memory versus what is acceptable reference knowledge? To investigate the open-everything approach, Weiman "investigates open-book, open-notes, open-internet" as a corollary to another course at his institution that is completely closed-book and no calculators allowed" [16]. He makes the following appeal to desired outcomes: "is it to test the ability to solve contrived barely realistic physics problems as if on a desert island" or to be able to prove you can function in the profession as it will be in the real-world with all available desired references? The two extremes offer very appealing contrast to one another. Weiman posits that if professors "want our students to learn to be effective real-world problem solvers and to have them perceive [their STEM field] as providing them with valuable tools for tackling such problems, we need to be testing them with solving realistic problems under realistic conditions" [16].

In assessment of the student-provided note sheet, Weiman hypothesizes that "it is beneficial to have students do activities that have them reflect on the course material and how it is organized, such as what they would do in preparing a cheat sheet, but that should not be made an either/or choice coupled with the kind of exams that we give" [16]. Weiman further hypothesizes that open-everything exams are better predictors of future success, stating that the more "exams resemble solving authentic problems in realistic environments, the more meaningful measures they will be of how our students will be able to perform in the environments they will find themselves in their future" [16]. While providing logical arguments and an interesting approach Weiman fails to provide analytical justification to his claims. Further, he does not recognize that student assessments are not limited to exams, but that course learning and assessment can also come from design projects, laboratories, or other collaborative deliverables. Perhaps written exams might be more suited to assessing fundamentals while more advanced concepts are better suited to other assessments.

Research Motivation and Methodology

The main motivation for conducting this research is based on student feedback from previous years and from instructor experience with successful examination techniques from other courses.

Motivation

The spring version of the Helicopter Aeronautics course conducted in 2019 allowed students to make their own note sheets in which they were expected to write-down or memorize any or all applicable equations they may need on the exam. General feedback from the students was that some students did not have the knowledge or did not write down one or more of the applicable equations required for certain exam questions. Therefore, these students were unable to complete significant portions of the exam while those students who prepared more thoroughly were much more successful. The 2019 course iteration authorized the use of a student-provided note sheet. The latest model was a change from a previous open-book examination model. A change to student-provided note sheets was explored because students were reportedly using the improper equations on their exams. The first exam results from 2019 illustrate this observation. Out of the 34 students in the course, four received failing grades, an 11.9% failure rate. Common among each failing exam was a complete correlation with incomplete or blank portions of the problem-solving section of the exam. The instructor spoke with the students and for each case, the student did not complete that portion of the exam because they did not write the correct equation on their prepared note sheets. This led to exploring potential changes that might address this discrepancy.

Theory and Methodology

Based on the results of previous research, perhaps the best learning outcomes would stem from a mix of authorized reference sources and assessment styles throughout the course. Such a hybrid approach could include the best features of previously conducted research. Perhaps teaching the course alongside a companion reference data card could help to highlight key equations to students along the way. This could additionally allow quick reference of previously taught equations for continued synthesis of new material to old material aiding to tie the course together as the students move further along. Regarding exam references, the companion reference data card might only be authorized for use on a portion of the exam to avoid over-emphasis on it as a reference. By having a portion of exams with no references it could demand students understand the fundamentals while concepts with greater complexity would allow students to use the reference data card along with a student-provided note sheet. This would seek to help channel the desired learning reflection and review process that stems from the creation of such a note sheet. Then, in the spirit of assessing the real-world environment as would be done with “open-everything” assessments, a design project and two laboratory analyses would authorize use of the textbook, notes, internet, and collaboration with others, to form a truly realistic engineering environment sought by this approach.

In addition to this theory, instructor experience teaching various engineering courses across the department offered insight into other successful techniques involving the use of a course-provided reference data card. Out of 12 courses surveyed in the Department of Civil and Mechanical Engineering, many other courses used a variety of the references previously outlined, sometimes in combination with one another, as presented in the figure below.

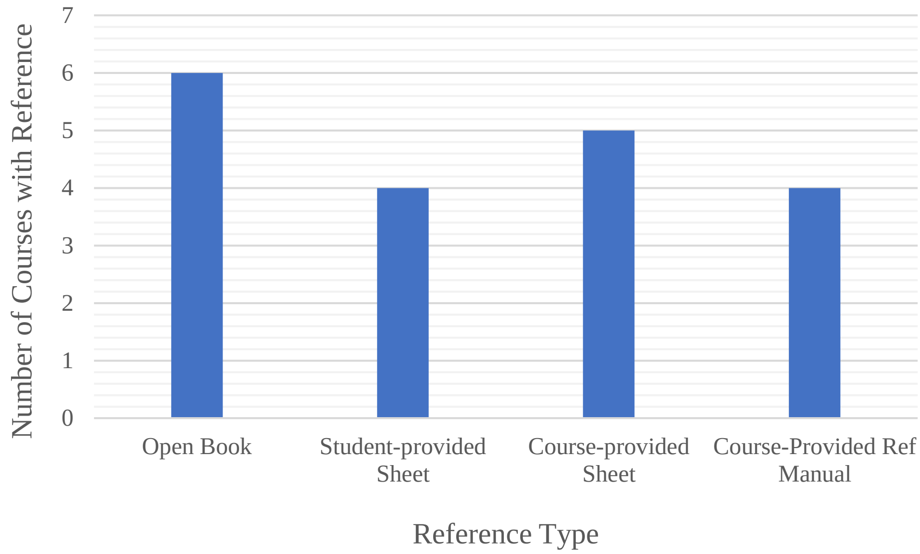

Figure 1. Authorized Exam References in 12 Engineering Courses

Based on the above theory and demonstrated potential in other courses for success using a course-provided RDC, a pilot study was conducted in the 2020 iteration of Helicopter Aeronautics to attempt to offset previous course iteration concerns by offering a companion "Reference Data Card." This study compares previous grades earned using the earlier course iteration with student-provided note sheets to those of the pilot program in 2020 using the new companion, double-sided, 8½ x 11 inch, course-provided reference data card (RDC). The efficacy of the approach is assessed from student anecdotal feedback, student survey data, and exam grade comparisons.

Course-provided Reference Data Card Design

In developing a new course reference data card there are several important design considerations. It is important to ask how much is too much material on the provided reference when striking a balance between forcing students to learn the material and providing a useful companion.

Design considerations of a course-provided reference sheet go beyond looking for the perfect amount of equations but must also consider several other facets. Some of the features that Raadt examined in student-provided reference sheets were the density of their notes, organization, comparison of the notes order to course content order, if they included example problems, abstract representations, sample answers, of duplicated the any portion of the text verbatim [4]. The most successful outcomes were those students with a logical, neat, and consistent approach with fundamental equations. Students with disorganized approaches or example problems tended to perform much worse.

In discussing this tradeoff, Rehfuss explored that the derivation of certain fundamental equations “should be within the capability of a student who is asked to remember the fundamental conservation principle.” Thus, he argues “a student need remember only Newton’s second law in original form, force as rate of momentum change, and from it can quickly derive the first and third laws of motion by considering an isolated system” [8]. On the opposite end of the spectrum, however, are complex relationships that are sometimes involve experimentally derived empirical formulas. Such formulas would hardly warrant memorization. Thus, the trade-off is between which types of equations to include and which fundamental relationships, if any. It seems such equations can be grouped into three groups: (1) fundamental equations, (2) derivations from fundamentals, and (3) empirical or experimentally derived equations.

Alongside which equations to include, content organization is also an important consideration. Should the layout title each equation or put them into into logical conceptual areas with a group title? Perhaps the equations should just speak for themselves with no titles or reference to what the variables in the equations are at all. Within the equation groups, would it be prudent or important to supplement the equations with any additional material? Such material could potentially include a list of defined variables, definitions, diagrams, a rotary wing cut-out with key vectors and variables for the fundamental equation, or problem-solving algorithms for a particular problem. Another consideration in designing the layout and content of a course-provided reference card is how it will be used in the course. Will it be incorporated into daily instruction as a companion reference alongside the student in every lesson or is it for use only during exams? The purpose of the card may better inform the designer on how much fundamental material is appropriate. It might be prudent to include more fundamental material on companion reference than one that is for one-time exam use. The purpose of the reference will help drive these design considerations.

In developing the Helicopter Aeronautics reference data card, the overall intended use is to be a course companion two-page equation sheet to eventually be combined with a student-provided note sheet for certain exam portions. The features include a logical structure matching the order that content is delivered in the course, with the appropriate equations that are not so simple that they should be memorized conceptual principles but rather equations that do not merit memorization. Theses equations include experimentally derived equations that students are not expected to memorize. Furthermore, students are told that not all of the equations they may need are on the course-provided sheet and that they need to understand the concepts and complex phenomena behind them for portions of the exam that are closed book.

Evaluation and Discussion

Three course achievement assessments were used in both iterations and covered the same concepts. Each iteration had one 30-minute exam on material from Lessons 1-7, a full 75-minute exam on Lessons 1-13 on “Hover Theory and Axial Climb and Descent Theory and Application,” and a second full 75-minute exam on Lessons 15-20 on “Forward Flight.” The final 10 lessons are assessed with the laboratory report and aircraft design project. The main indicators used were comparison of course feedback and exam results from the full 75-minute examination covering material from Lessons 1-13 of the 30-lesson course. The exam consists of short answer conceptual questions and long answer multi-part calculations requiring extensive use of equations from the textbook.

31 students took a comparable exam in 2020 to the 34 students in 2019. The students were authorized the course companion RDC on the 2020 exam while students in 2019 were only authorized their student-provided note sheet. The overall exam average went up 0.75% from 85.9% to 86.65%. Failures went down from four failures in 2019 to zero failures in 2020. However, when broken apart by problem-type, students scored on average 66.51% of available points on the conceptual problems as compared to a striking 91.72% on the problem-solving portion. This appears to be a decrease in conceptual understanding from 77.6% and an increase in problem solving from 85.9% in 2019.

In a survey of 31 students enrolled in the 2020 course, 23 responded to a list of questions rated on a Likert scale from 1 through 5, ranging from strongly disagree to strongly agree. 100% of students reported referring to the RDC during the exam. All students agree or are neutral that the equations are more important in application than in memorization. 100% of students agree that the RDC is a useful guide in moving from lesson to lesson throughout the course. 95% of students report that having the RDC reduces exam anxiety while 65% report it changes the way that they take an exam. 91% of students report being better able to understand the course concepts. 39% of students spend as much time studying as if they did not have an RDC, while 61% spend less time preparing for an exam as a result. Perhaps this is because they do not need to highlight or tab their books or spend time preparing note sheets but can rather spend more time on practice problems and understanding the fundamental concepts. Figure 2 shows the Likert scale survey results.

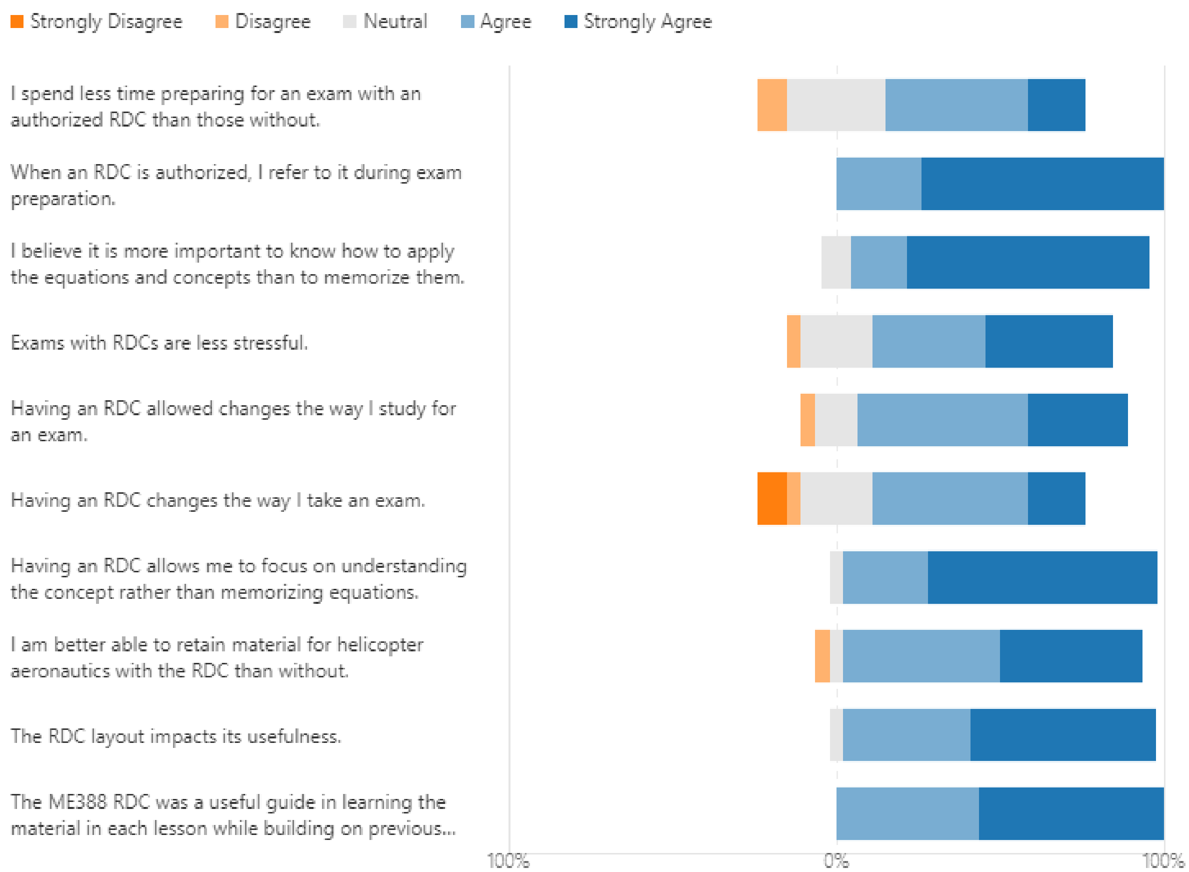

Figure 2. Course Survey Results (2020)

When asked "what would you add or remove from the RDC?" 17 of the 23 survey responses had a non-blank answer. Of those, 6 suggested adding variable lists or constants, 3 suggested adding definitions, 3 suggested adding diagrams, 2 suggested adding equations, and 1 suggested removing equations. When asked "what other impacts did the RDC have on your learning in the course?" 14 of the 23 survey responses had a non-blank answer. Of those, 4 answered that it aided in completing course homework, 4 that they spent less time in the book during studying because they had the entire course together in one organized spot, 4 that the logical order of material helped in understanding the whole course together, and 3 that the RDC improved their overall studying ability and comprehension.

Overall, the intent of moving from a student-provided notes sheet to a course-provided reference sheet aimed at reducing exam failures by avoiding concerns of not having or using the appropriate equations. The course evolved from an open book exam to student-provided note sheets, and finally to a course-provided note sheet while attempting to continuously improve student comprehension and understanding as gauged through assessment on examinations. The results show a decrease in failures with no marked improvement in course averages. Conceptual assessment scores decreased slightly. Students report themes of better material compression with more ability to work on problems. However, more data is needed to assess comprehension of conceptual aspects.

Conclusion

It is possible that moving from student-provided note sheets to course-provided note sheets reduced the course exam failure rate from 11.8% to 0%. All or greater than 90% of students responded positively to how the course-provided reference sheet affects their comprehension, preparation, test-taking, and overall understanding of the course material.

Future work requires more data and a breakdown of conceptual scores versus problem solving scores. Further assessment should be conducted to assess the validity of the hybrid approach outlined in this work to determine any trends towards student improvement or degradation of both conceptual and problem-solving proficiency. Data should be compared with incoming student grade point averages to offset potential external influences. Once a trend is recognized, the course can alter the references approach towards more or less course-provided material and adjust the content or organization of such material.

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