AC 2008-1507: COMPARISON OF DIFFERING CREDIT HOUR ALLOTMENTS FOR THERMODYNAMICS AND FLUID MECHANICS COURSES

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Comparison of Differing Credit Hour Allotments for Thermodynamics and Fluid Mechanics Courses

Abstract

Each institution determines how many credit hours will be allotted for each course. Thermodynamics and fluid mechanics in an undergraduate Bachelor of Science Mechanical Engineering curriculum in the United States typically are allotted three or four credit hours. For a semester system, this allows for 42-45 or 56-60 fifty-minute class sessions in three and four credit hour courses, respectively.

Opinions vary whether thermodynamics and fluid mechanics should each be three credit hours, each be four credit hours, or one should be three and the other four. Two universities have conducted a study to determine the advantages, disadvantages, and consequences of three vs. four credit hours. One university has a four credit hour thermodynamics and a three credit hour fluid mechanics, while the other university has exactly the opposite. Through student surveys, course objectives/outcomes, course syllabi, instructors' experiences, and average grades, conclusions are drawn on the effects of course length. Other issues are examined such as challenges facing instructors who have previously taught a four credit hour course that now must cover the same material within a three credit hour allotment. Finally recommendations are given for instructors that are allotted less than desirable credit hours.

1. Introduction

Each undergraduate Bachelor of Science Mechanical Engineering program in the United States is free to determine how many credit hours are allotted for each course in the curriculum. Some institutions operate with semesters, others with quarters and still others with trimesters. For any one of these systems, some mechanical engineering (ME) curricula require two thermodynamics courses while others require only one. Most ME curricula only require one fluid mechanics course. This paper is applicable for institutions that operate on the semester system with ME programs that require only one thermodynamics course and one fluid mechanics course. For these programs thermodynamics and fluid mechanics are typically allotted three or four credit hours. Since a typical semester is 14-15 weeks, three credit hours allows for approximately 42-45 fifty-minute class sessions, and four credit hours allows for approximately 56-60 fifty-minute class sessions.

Opinions vary whether thermodynamics and fluid mechanics should each be three credit hours, each be four credit hours, or one should be three and the other four. Mechanical engineering faculty at Lawrence Technological University (LTU) in Southfield, Michigan and at the University of Evansville (UE), Indiana have conducted a study to determine the advantages, disadvantages, and consequences of three vs. four credit hours. UE has a four credit hour thermodynamics course and a three credit hour fluid mechanics course, while LTU has exactly the opposite. This paper will draw conclusions as to the recommended course length for thermodynamics and fluid mechanics through various comparisons. First, course objectives/outcomes will be compared. Next, course content and number of classroom hours spent on each topic will be compared. Student surveys were administered and the opinions and comments of the LTU and UE students will be compared. Next a few common exam problems were administered in fluid mechanics sections and the student scores will be compared. Other issues are examined such as challenges facing instructors who have previously taught a four credit hour course and must cover the same material within a three credit hour allotment. Finally recommendations are given for instructors that must deliver course content in fewer hours than would be preferred.

2. Course Objectives Comparison

Thermodynamics

Objectives for each course in an ME curriculum are composed and submitted during EAC/ABET assessment.

The three credit hour thermodynamics course at LTU has the following objectives:

"By the end of this course, the student will be able to:

- Identify the proper control mass or volume to effectively solve thermodynamics problems.
- Recognize the difference between states, processes, and cycles.
- Define state, phase, and pure substance.
- Identify work and heat interactions between a system and its surroundings.
- Describe a quasi-equilibrium process.
- Solve simple polytropic process problems.
- Recognize kinetic, potential, and internal energy of a system.
- Produce a property diagram for a thermodynamic process or cycle.
- Utilize the compressed, saturated, and superheated property tables along with associated quality equations to identify state properties.
- Utilize the ideal gas equation of state and gas tables to solve state properties.
- Utilize the concepts of conservation of energy to solve control mass problems for ideal gases and pure substances.
- Utilize the constant specific heat model to solve First Law of Thermodynamics problems.
- Utilize the compressibility chart to approximate an ideal gas analysis.
- Recognize steady flow devices including turbines, compressors, pumps, fans, nozzles, diffusers, heat exchangers, mixing chambers, and throttling valves.
- Simplify the conservation of mass and energy equations so that it will properly apply to the problem at hand.
- Utilize the concepts of conservation of mass and energy to solve steady state control volume problems for ideal gases and pure substances.
- Identify transient First Law of Thermodynamics problems.
- Define briefly or summarize the Second Law of Thermodynamics.
- Distinguish heat engines, refrigeration cycles, and heat pumps.
- Determine thermal efficiency for heat engines and coefficient of performance for refrigeration cycles, and heat pumps and identify its significance.
- Recognize reversibilities and irreversibilities.
- Identify the Carnot cycle.
- Solve entropy balance problems for a control mass.

- Solve entropy rate balance problems for steady state control volumes.
- Define the concept of isentropic processes.
- Utilize the concepts of isentropic efficiency to solve steady flow device problems involving incompressible and compressible fluids.
- Recognize and solve basic Rankine, Otto, and Brayton cycle problems using principles of the First and Second Law of Thermodynamics.
- Demonstrate an elementary ability to solve an open-ended thermodynamics design problem."

Course objectives are broader and briefer for the four credit hour thermodynamics course at UE.

"Students will be able to

- Evaluate properties of substances using tables and simple algebraic models.
- Perform mass and energy balances for closed and open systems.
- Perform second law analysis of thermodynamic systems.
- Understand cycles for power generation and refrigeration."

Although written in different style and detail, the LTU and UE objectives are nearly the same except for one important difference. The UE course objectives include an understanding of refrigeration cycles. The LTU course barely can cover power generation; refrigeration cycles are not covered. Clearly, with the extra credit hour, UE can cover more material which leads to more outcomes. In fact, as will be addressed in the next section, the extra credit hour in the UE course allows for more than just the addition of the topic of refrigeration.

Other than the one outcome difference, each student at either university should achieve similar outcomes by the completion of the course. It is likely that the outcomes similar to each course are representative of any ME program's standard one semester thermodynamics course. Unfortunately, these outcomes must be achieved in a shorter time allotment when the course is three credit hours instead of four. This could be detrimental to the student, because thermodynamics is a foundational course necessary for a mechanical engineer; the outcomes obtained are needed in subsequent courses (both required and elective), laboratory work, and capstone projects.

<u>Fluid Mechanics</u>

The four credit hour fluid mechanics course at LTU has the following objectives:

"By the end of this course, the student will be able to:

- Define viscosity, Newtonian fluids, and general fluids terms (e.g., specific gravity.)
- Solve hydrostatic problems including manometers and flat and curved submerged surfaces.
- Utilize the Bernoulli Equation to solve inviscid flow problems.
- Utilize the Reynolds Transport Theorem to solve continuity and linear momentum problems.
- Identify the modes of fluid deformation and the assumptions for the Euler and Navier Stokes equations.
- Utilize differential analysis to verify incompressibility, irrotationality, and find acceleration, stream function, etc.
- Solve and plot a potential flow solution using stream function or potential function.

- Derive dimensionless groups and solve for similarity.
- Predict flows or pressure drops for single line piping systems.
- Solve boundary layer problems using Blasius solution and momentum-integral method.
- Solve for lift and drag using experimental results and predict terminal velocity, etc.
- Solve for drag of composite bodies.
- Predict speed of sound for ideal gases.
- Solve basic isentropic, Fanno, and Rayleigh 1-D compressible problems."

The three credit hour fluid mechanics course at UE does not have detailed objectives but instead very broad, whole-program-oriented objectives. Consultation with UE College of Engineering and Computer Science administrators and Fluid Mechanics course instructors reveals that the number and scope of specific course objectives from LTU also generally apply at UE, with a few subject matter differences. For example, potential flow solutions at LTU are replaced with pumping systems at UE, and some of the compressible flow objectives at LTU are replaced with open-channel flow objectives at UE. Therefore, even though the UE course has one fewer credit hour, the number and scope of specific objectives are nearly the same. Like thermodynamics, it is likely that the number and scope of objectives for any ME program's standard one semester fluid mechanics course are similar. Unfortunately, in some cases these outcomes must be met in a tighter time period when the course is three credit hours instead of four. This appears to be unfair to the student, since fluid mechanics student outcomes are necessary for subsequent coursework (e.g., heat transfer), laboratory work, and capstone projects.

3. Actual Course Content Comparison

Thermodynamics

Three sections of three-credit hour thermodynamics were taught at LTU during the Fall 2007 semester by three separate instructors. One section of four-credit hour thermodynamics was taught at UE during the Fall 2007 semester.

For each of the four thermodynamics sections, the course content and number of classroom hours spent on each broad topic are shown in Table 1. Nearly all the same material is covered regardless of the number of classroom hours allotted for the course. LTU Section 1 barely covered two-phase flow, LTU Section 2 did not cover two-phase flow, and LTU Section 3 did not get to the topics of power cycles and two phase flow. Some variation such as this will occur from instructor to instructor. The course at UE on the other hand had more time for power cycles than any LTU section, and also covered refrigeration and heat pump systems, ideal gas mixtures, and psychrometrics. If LTU students want these topics, they must get them in elective courses. It should be noted that UE has 14 class-weeks in a semester while LTU has 15 class-weeks.

Note there is a significant difference in exam and review hours. (Final exams are not considered here as each section administers a final examination during a separate final exam week.) Part of the reason for this disparity is because some instructors give four exams during the semester while others give two or three. Another major reason is that some of the thermodynamics sections meet twice a week for 1.5 hours instead of the traditional 1 hour class sessions. Therefore, each time an exam is given, a half-hour of lecture time is lost. With four exams, an instructor is losing two hours of classroom instruction. The instructor giving the four exams, however, considers the trade-offs are worth it, because this helps assess the student's competency in detail on focused subject matter with this number of examinations.

Topics	Classroom hours			
	LTU Section 1	**LTU Section 2**	**LTU Section 3**	**UE**
Introductory concepts and definitions	2	3	3	3
Energy and the First Law of Thermo	3	4.5	9	5
Properties of Pure Simple Compressible Substances	8	6	7.5	8
Control Volume Energy Analysis	7	4.5	6	7
The Second Law of Thermodynamics	3	5.25	6	4
Entropy	7	5.25	9	7
Vapor and Gas Power Cycles	6	6.75	0	9
Refrigeration and Heat Pump Systems	0	0	0	5
Two phase and compressible flow	1	0	0	0
Nonreacting Ideal Gas Mixtures and Psychrometrics	0	0	0	6
Exams and Review sessions total	9	9.75	4.5	2
TOTAL	45	45	45	56

Table 1. Thermodynamics course content and number of classroom hours spent on each broad topic

Fluid Mechanics

One section of three-credit hour fluid mechanics at UE during the Fall 2007 semester and one section of four-credit hour fluid mechanics at LTU during the Fall 2007 semester were analyzed for this paper.

For each of the fluid mechanics sections, the course content and number of classroom hours spent on each broad topic are shown in Table 2. Because the UE course enrolls both mechanical and civil engineering students, the course actually has to cover more topics in 42 classroom hours than the LTU course with 60 hours! As expected, most of the topics in the UE course were covered in fewer classroom hours. The consequences are: 1) speeding through material in class, 2) a smaller number of example problems (which students like) in order to cover more "theory (which students dislike), 3) heavier reliance on the textbook for detailed explanations (and examples), 4) extra instructor office hours for students that need assistance, and 5) perhaps a lower student understanding of the material.

	Classroom hours	
Topics	**LTU**	**UE**
Fluid Properties and Definitions	3	2
Fluid Statics	5	5
Bernoulli Equation and Pressure	4	0*
Fluid Kinematics	3	2
Finite Control Volume Analysis	7	8
Differential Analysis	5	2
Dimensional Analysis	5	4
Viscous Pipe Flow	9	8
External Flow	7	3
Open Channel Flow	0	3
Compressible Flow	4	3
Exams and Review sessions total	8	2
TOTAL	60	42
* This topic was covered in Finite Control Volume Analysis.		

Table 2. Fluid mechanics course content and number of classroom hours spent on each broad topic

4. Student Opinion

Instructors can augment or compress the required material in a thermodynamics or fluid mechanics course to fill as many or as few credit hours as necessary, but *teaching* the material is not the true goal. The instructor's function is to facilitate an experience where the students *learn* the material. An essential element of "learning facilitation" is ensuring that the material is presented at the proper pace and in "digestible" chunks. Also required is ample "soak-time" between class periods wherein the student can study and absorb the material, typically requiring the solving of homework problems. With too few class periods, too much material will be presented at once and the student may not comprehensively learn the material. The likely place to determine if the material is presented and learned at the proper pace is from the student. Therefore, thermodynamics and fluid mechanics students were surveyed during the last week of the Fall 2007 semester. The students were asked about the amount of material, the time-frame in which the material was presented, the pace of the course, etc. Much of the survey was quantified using a 5-point Likert scale, although written responses were also gathered.

The thermodynamics course results compiled in this paper are derived from 53 LTU student surveys (three sections) and 16 UE student surveys (one section). The fluid mechanics course results are derived from 19 LTU student surveys (one section) and 13 UE student surveys (one section). While some of these sample sizes are small, standard deviations of the students' responses are reasonable, indicating to the authors that the sample size is adequate.

Table 3 shows the percentage of students agreeing with statements about the course length and material in Thermodynamics. When reviewing the data, keep in mind that the UE thermodynamics course is 4 credit hours and LTU's is 3 credit hours. Bolded numbers are those that show high and/or significant percentages.

	strongly disagree		disagree		no opinion		agree		strongly agree	
	LTU	UE	LTU	UE	LTU	UE	LTU	UE	LTU	UE
This course covers too much material in too few classroom hours.	1.9	6.3	17.0	**56.3**	13.2	12.5	**43.4**	25.0	24.5	0
Without effecting my ability to learn the material, this course could have covered more material than we did based on the number of classroom hours.	**32.1**	31.3	**39.6**	**56.3**	11.3	12.5	15.1	0	1.9	0
So that I could have learned the same material better, this course should have a credit hour added.	5.7	12.5	5.7	**43.8**	15.1	31.3	**45.3**	12.5	28.3	0
Considering the exact same material covered this semester in this course, I would prefer a credit hour added so that it gives the instructor more class time to explain the material, do more examples in class, etc.	1.9	6.3	5.7	**37.5**	13.2	6.3	**45.3**	**50.0**	**34.0**	0
I would prefer a credit hour added to this course so that more material/topics can be covered.	7.5	6.3	18.9	**62.5**	18.9	12.5	**39.6**	18.8	15.1	0
This course should have fewer credit hours.	**60.4**	**50.0**	28.3	**50.0**	3.8	0	5.7	0	1.9	0
This course has just the right amount of credit hours.	22.6	0	**37.7**	6.3	20.8	12.5	17.0	**62.5**	1.9	18.8

Table 3. Percentage of LTU and UE Thermodynamics students agreeing with the statements concerning

Table 4 presents the same material as Table 3 except with the actual ratings from the 5-point scale, which to some is a bit easier to read. A conclusion column has been included. It appears that students prefer a 4 credit hour thermodynamics course, not necessarily to add more material, but to ensure that they can learn the given material.

Table 5 shows the percentage of thermodynamics students rating the pace of the course. While neither UE nor LTU students found the pace of the course slow, most UE students found the course just right, but 85% of the LTU students found the course fast. On a scale of 1 to 5, where 1 is too slow and 5 is too fast, the average LTU student response was 4.06, the median was 4.00, and the standard deviation was 0.60. The average UE student response was 3.38, the median was 3.00 and the standard deviation was 0.50.

The evidence presented in Tables 3 through 5 indicates that students believe that 4 credit hours is optimal for the amount of material that should be learned in a thermodynamics course. It should be noted that adding a credit hour to a course at LTU, without a corresponding reduction in a credit hour from some other course, would *add* to a student's tuition, while adding a credit hour at UE would not. Therefore, when the student's imply that a credit hour should be added to the thermodynamics course at LTU, it is a very strong statement. (Nobody wants to pay more for the same product unless there is truly value added.)

	Average		Median		Standard deviation		Conclusion
	LTU	UE	LTU	UE	LTU	UE	
This course covers too much material in too few classroom hours.	3.72	2.56	4	2	1.08	0.96	Need more than 3 classroom hours/wk
Without effecting my ability to learn the material, this course could have covered more material than we did based on the number of classroom hours.	2.15	1.81	2	2	1.10	0.66	Could not cover more material
So that I could have learned the same material better, this course should have a credit hour added.	3.85	2.44	4	2	1.08	0.89	Course should be 4 credit hours
Considering the exact same material covered this semester in this course, I would prefer a credit hour added so that it gives the instructor more class time to explain the material, do more examples in class, etc.	4.04	3.00	4	3.5	0.94	1.10	Course should be 4 credit hours
I would prefer a credit hour added to this course so that more material/topics can be covered.	3.36	2.44	4	2	1.18	0.89	Course should be 4 credit hours
This course should have fewer credit hours.	1.60	1.50	1	1.5	0.95	0.52	Course should be 4 credit hours
This course has just the right amount of credit hours.	2.38	3.94	2	4	1.08	0.77	Course should be 4 credit hours

Table 4. Thermodynamics students' ratings of statements concerning credit hours, amount of material, and ability to learn. On a scale of 1 to 5, 1 indicates "strongly disagree" and 5 indicates "strongly agree."

	too slow		somewhat slow		just right		somewhat fast		too fast	
	LTU	UE	LTU	UE	LTU	UE	LTU	UE	LTU	UE
The pace of this course was	0	0	0	0	15.1	**62.5**	**64.2**	37.5	20.8	0

Table 5. Percentage of LTU and UE Thermodynamics students rating the pace of the course

Table 6 shows the percentage of students agreeing with statements about the course length and material in Fluid Mechanics. When reviewing the data, keep in mind that the UE fluid mechanics course is 3 credit hours and LTU's is 4 credit hours. Bolded numbers are those that show high and/or significant percentages.

	strongly disagree		disagree		no opinion		agree		strongly agree	
	LTU	UE	LTU	UE	LTU	UE	LTU	UE	LTU	UE
This course covers too much material in too few classroom hours.	5.3	0	**57.9**	30.8	10.5	30.8	26.3	**38.5**	0	0
Without effecting my ability to learn the material, this course could have covered more material than we did based on the number of classroom hours.	15.8	30.8	**68.4**	**53.8**	5.3	7.7	10.5	7.7	0	0
So that I could have learned the same material better, this course should have a credit hour added.	21.1	0	**36.8**	23.1	21.1	7.7	21.1	**53.8**	0	15.4
Considering the exact same material covered this semester in this course, I would prefer a credit hour added so that it gives the instructor more class time to explain the material, do more examples in class, etc.	21.1	0	31.6	7.7	5.3	15.4	**42.1**	**69.2**	0	7.7
I would prefer a credit hour added to this course so that more material/topics can be covered.	26.3	0	31.6	46.2	26.3	15.4	15.8	38.5	0	0
This course should have fewer credit hours.	26.3	46.2	**42.1**	**53.8**	21.1	0	10.5	0	0	0
This course has just the right amount of credit hours.	0	7.7	15.8	**38.5**	26.3	30.8	**47.4**	23.1	10.5	0

Table 6. Percentage of LTU and UE Fluid Mechanics students agreeing with the statements concerning

Table 7 presents the same material as Table 6 except with the actual ratings from the 5-point scale, which to some is a bit easier to read. A conclusion column has been included. As was the case with thermodynamics, it appears that students prefer a 4 credit hour fluid mechanics course, not necessarily to add more material, but to ensure that they can learn the given material.

Table 8 shows the percentage of fluid mechanics students rating the pace of the course. On a scale of 1 to 5, where 1 is too slow and 5 is too fast, the average LTU student response was 3.58, the median was 4.00, and the standard deviation was 0.61. The average UE student response was 3.85, the median was 4.00 and the standard deviation was 0.55. While only one LTU student (5.3%) and no UE students found the pace of the course slow, most students found the course somewhat fast. In other words, there is a lot of material to learn in fluid mechanics even with 4 credit hours. The UE instructor who had to present the same (actually more!) material in three credit hours had to use some very creative classroom methods as well as shift some of the burden to the students out-of-class time. On the other hand, as will be seen in the next section, just because the UE students did not find the pace too fast, their grades and performance in learning the material may have been affected

	Average		Median		Standard deviation		Conclusion
	LTU	UE	LTU	UE	LTU	UE	
This course covers too much material in too few classroom hours.	2.58	3.08	2	3	0.96	0.86	Need more than 3 classroom hours/wk
Without effecting my ability to learn the material, this course could have covered more material than we did based on the number of classroom hours.	2.11	1.92	2	2	0.81	0.86	Could not cover more material
So that I could have learned the same material better, this course should have a credit hour added.	2.42	3.62	2	4	1.07	1.04	Course should be 4 credit hours
Considering the exact same material covered this semester in this course, I would prefer a credit hour added so that it gives the instructor more class time to explain the material, do more examples in class, etc.	2.68	3.77	2	4	1.25	0.73	Course should be 4 credit hours
I would prefer a credit hour added to this course so that more material/topics can be covered.	2.32	2.92	2	3	1.06	0.95	Students do not want extra credit hour for more topics
This course should have fewer credit hours.	2.16	1.54	2	2	0.96	0.52	Course should be 4 credit hours
This course has just the right amount of credit hours.	3.53	2.69	4	3	0.90	0.95	Course should be 4 credit hours

Table 7. Fluid mechanics students' ratings of statements concerning credit hours, amount of material, and ability to learn. On a scale of 1 to 5, 1 indicates "strongly disagree" and 5 indicates "strongly agree."

	too slow		somewhat slow		just right		somewhat fast		too fast	
	LTU	UE	LTU	UE	LTU	UE	LTU	UE	LTU	UE
The pace of this course was	0	0	5.3	0	31.6	23.1	63.2	69.2	0	7.7

Table 8. Percentage of LTU and UE Fluid Mechanics students rating the pace of the course

Now let us assume that only one of the two courses could be 4 credit hours and the other had to be 3 credit hours. While a formal comparison of thermodynamics to fluid mechanics data has not been completed, visual inspection reveals that there is a case to be made for either course to be 4 credit hours. For example, the fluid mechanics students believe the pace of the course is fast even with 4 credit hours. On the other hand, thermodynamics is a core course with concepts that span into fluid mechanics, heat transfer, combustion, etc.

Student comments

For the LTU Thermodynamics course, the three-credit hours often meant that the students had to spend an extra amount of time outside of class to fully understand and "digest" the material. It is traditional to expect a student to spend two to three hours studying outside of class for every one hour spent in class, but many students reported more than that. Some of the comments that attest to this follow:

- "A lot of material was covered very quickly. One more credit hour would significantly help students understand the topics a little more clearly. Even though this was a 3 credit hour course, on average I spent over 12 hours or more per week outside of class looking over notes or doing homework."
- "Professor expected us to spend 10+ hours outside of class for studying. Too much time expected for so few credit hours."
- "It is definitely the most time-consuming course I've taken, especially for 3 credit hours. However, it's not impossible to do well and learn a lot. I'm now very confident in my Thermodynamics knowledge."
- "I think this course is enjoyable, but it takes up a lot of time and as a result, my other classes suffer."

The general theme of the comments indicates that four credit hours is preferred:

- "I think adding 1 more credit hour would really help with trying to absorb thermodynamics. It is an important course and lays a solid foundation for courses to come."
- "A lot of material was covered with little time for examples. Difficult to retain/digest information."
- "Do not feel that I learned as much as I could of because of the fast pace."
- "Not enough time was available to adequately examine some topics. It seemed as if some topics were not covered thoroughly enough due to time constraints. An additional credit hour would seem to allow enough time to fully cover these topics, so long as a large amount of additional topics were not added."
- "Thermo covers a great deal of information in a small amount of time. I think an extra credit hour would be a great addition."
- "I feel that the material that was covered was Extremely Important and I wish that I had been aware of the amount of information that would be covered in the course before I planned out my semester. I suffered in other courses as well as this one trying to keep up."

One student wanted an additional credit hour to adequately cover the current material, plus one more credit hour to add more material: "There is way too much information to cover in 3 credits. I think the class should be (5) five credits and cover more material." Another student suggested an additional course in thermodynamics: "I think an 'intro' course might be more beneficial than an extra credit hour to accommodate all the material covered. An extra credit hour for examples is a plus too, but there is still way too much material for a 3 credit hour course."

Although the majority of the LTU thermodynamics students wanted an extra credit hour, some of them believed that three credit hours was fine (albeit difficult). It should be noted that the following two comments came from students in the only section that did not cover vapor and gas cycles (i.e., their section covered the fewest topics).

- “There IS a lot of information covered in this course, but with the correct amount of study time, it is quite bearable. The student just CAN'T fall behind. If this happens, get assistance right away.”
- “I enjoyed the course as is; if more material is going to be covered then another credit should be added.”

For the four credit hour UE thermodynamics course, the students commented that the course was appropriate with four hours:

- “I thought we covered the material sufficiently with 4 credit hours and kept a good pace and covered a lot. I wouldn't change it.”
- “This class allowed for ample amounts of examples and time to review. Less material would have made the class go too slowly.”
- “Plenty of time was spent on beginning concepts, allowing for us to learn applied thermodynamics faster.”
- “I would have liked to cover more material, but the workload would have been much too large.”

The students for the three credit hour UE fluid mechanics course were complaining some about the pace of the course, but no one explicitly commented about adding a credit hour:

- “I feel like the amount of material covered was good, but a little more time on each topic would also be nice.”
- “Up until the last two/three weeks into the semester, I felt that material was slightly rushed for the amount needed to be retained.”

Two students commented on the difficulty of the exams. These comments indicate that the material was rushed which produced bad retention for an exam.

- “Pace was a little fast at times. Tests were a killer, although probably my own fault. They were still very difficult.”
- “This is a good class, but I found it hard to pick up on some of the material. The homework was good, but the tests were difficult.”

For the four credit hour LTU fluid mechanics course, one student was very explicit as to the preferred length of the course: “Any less credit hours for Fluid Mechanics would cut too much time off to correctly learn the material.” Another student stated, “The class seemed to cover enough material without being too hard. More time for examples would be nice, but I am not sure it is worth the cost of an extra credit hour.” Since these fluid mechanics students had already experienced a three credit hour thermodynamics course and were just finishing a four credit hour fluid mechanics course, three students commented on thermodynamics course length.

- “This class is fine. Thermo should also be 4 credits….”
- “Good class overall, pace is a little fast but nothing to really worry about. I think Thermo and Fluids should both be 4 credit hours.”
- “One less credit hour in FM would cause us to rush even more. 3 credit thermo was fine, but 4 hour thermo would allow us to cover more. My suggestion: 4 hours for both thermo and FM.”

The survey results and the comments seem to indicate that students prefer four credit hours for both courses.

5. Common Exam Problems Grade Comparison

Two common exam problems were given to the fluid mechanics students at LTU and UE. One problem covered the topic of flow through a pipe and the other problem covered the topic of drag force. The pipe flow problem on the UE exam was slightly different than the LTU exam problem; the UE problem did not include minor losses as that topic had not yet been covered when the exam was administered.

At UE, drag problem scores were recorded for 13 students, while at LTU, drag problem scores were recorded for 19 students. Unfortunately, for the pipe flow problem, less than half of the UE student scores were obtained (six), while 20 LTU student scores were obtained. The UE student scores for the pipe problem were obtained through email communication after the graded exam was returned to the students, so it is possible that the student scores were obtained from the more conscientious students. For completeness, both problem scores are presented below, but the pipe flow problem scores may be statistically meaningless.

The averages and the medians (converted to a percentage basis) on Table 9 indicate that the drag force problem scores were higher at LTU which has a four credit hour course and which consequently could allot more time for the external flow topic (see Table 2). The standard deviation is nearly the same between institutions indicating that the distribution of scores was not a major factor. Also at both institutions the median was consistently higher than the average indicating that students as a whole did better than the average suggests.

	LTU	UE
Average	79.7	65.3
Median	88.8	74.3
Standard Deviation	21.2	21.8

Table 9. Student scores in percent for the drag force exam problem

Table 10 unexpectedly indicates that UE students in a three credit course scored higher than the LTU students, but as noted above, the data may be statistically meaningless. The UE median is nearly 12% higher than the average suggesting that mostly only the "better" students submitted scores. (The instructor's opinion corroborates this hypothesis.) The higher standard deviation supports this as well. In addition, the LTU problem may have been slightly more difficult because of the addition of minor losses. Therefore the higher UE scores may be an anomaly. On the other hand, Table 2 indicates that the instructors allotted nearly equal classroom hours to the topic of viscous pipe flow. Since the LTU problem may have been slightly more difficult, perhaps the UE scores should be slightly higher which contributes to the argument that classroom hours are a significant factor to student grades.

	LTU	UE
Average	68.3	73.3
Median	66.9	85.0
Standard Deviation	21.8	25.4

Table 10. Student scores in percent for the pipe flow exam problem

A larger student sample size and data for additional exam problems may better delineate the difference (if any) between a three credit and four credit hour course, but not surprisingly, preliminary data suggests that students gain better understanding for each topic through a four credit hour course.

6. Another Possible Future Study

It would be very beneficial to compare average course grade (i.e., quantify the average grade difference) and grade distribution for a 3 vs. 4 credit hour course when the same number of topics is covered. Unfortunately, there is too much variability between length of coverage for any given topic between instructors to give a meaningful comparison. The obvious speculation is that, given the same instructor, the average of all students' grades would be lower when covering the same number of topics in a three credit hour class than a four credit hour class. This conclusion is likely true regardless of the course.

7. Other Issues

Because of the knowledge base needed by a student for subsequent coursework, laboratory work, and capstone projects, the course objectives and outcomes usually cannot be changed to accommodate the number of classroom hours allotted for a course. Therefore, when adjusting to varying credit/class time allotments for the same objectives/outcomes, instructors generally have five choices:

1. Cut back on some of the material to be covered
2. Go faster
3. Shift more of the burden for learning to the students (and more of the burden for teaching to the textbook)
4. Change teaching methods and the use of "tools"
5. Expand office hours, and/or include out-of-class informal topic specific colloquia sessions for more detailed review

Possibly the most common solution, and the one preferred by many students, would be the first. Natural variations among instructors and/or class dynamics often cause this to happen – this was the case in two of the three LTU Thermodynamics sections. While it is certainly true that both thermodynamics and fluid mechanics have a number of "essential" topics, it is equally true that no two institutions, or even no two instructors, can agree completely on what they are! Nevertheless, this study shows that the essentials are nearly identical between the two institutions so neither of them has decided to substantially eliminate material from the shorter (3 hour) course.

Simply going faster is clearly a bad idea; after all, the objective is learning, not teaching. An "expert" might be able to cover all of the essentials in a single lecture, especially if s/he has auctioneer's training, but this would not facilitate learning. There are, however, ways to go faster while not significantly affecting student learning, as described below under "Recommendations".

Shifting the burden to the students should be considered with some care. After all, the educator's task is to help the student become a life-long learner so a significant portion of true learning probably should take place outside the classroom. This should not be carried to extremes; students have many other demands besides thermodynamics and fluid mechanics courses and instructors should be careful not to demand more than their "fair share" of students' time. For significant learning to take place outside of class, the textbook selected must be appropriate to the instructor's style and the coverage of essential topics must be strong.

No matter how many credit/classroom hours are allotted, instructors should always seek to use a variety of teaching methods (addressed in the "Recommendations" section). Arguably, more tools are available for fluid mechanics than for thermodynamics. A wide variety of visual media are available, ranging from the classical National Committee for Fluid Mechanics Films (NCFMF; now available as streaming video)[1] to materials on CD and DVD that are supplied with textbooks.

The last choice of expanded office hours, and/or adding informal colloquia sessions, while effective, places added burden on both the student and the instructor. The student, however, has the option to participate voluntarily, but the instructor is now obligated to prepare and participate, regardless of the number of students attending the colloquia. It also, essentially, adds the extra faculty contact time with the student without officially acknowledging the effort of either party involved. It should be noted that one LTU Thermodynamics instructor has done this on an intermittent basis to help the students, and it has resulted in good success. Unfortunately, it is extra work without the recognition.

One of the authors of this paper had to modify fluid mechanics from a 4 credit hour format to a 3 credit hour format because of a curricular change. Changes made included:

- Eliminating a student "design" project in order to spend more time on fundamental concepts.
- Converting to extensive use of Power Point, especially using publisher-supplied textbook figures and text and development of "overview" slides. In each class session, copies of slides were given to students for note-taking.
- Assigning several "short essay" (a few sentences or a paragraph) concept questions as homework in addition to the standard analytical problems.
- Assigning two written reviews of NCFMF video programs ("Pressure Fields and Fluid Acceleration" and "Fluid Dynamics of Drag")[1]. Students viewed the programs on their own time and on their own computers outside of class time.

As a result, the pace was somewhat more intense. Student reactions are documented above. Additionally, the instructor's student ratings suffered slightly and, not surprisingly, students commented that they would like to see more example problems in class.

8. Recommendations

There are several techniques that instructors can consider to more effectively cover material at a more intense pace while not sacrificing student learning.

Probably the most important recommendation is: "Don't waste precious class time." Arrive on time and expect the same of students. Use all of the allotted time. Spend your time on clarifying important concepts. Make homework assignments in advance or have them written on the board, Power Point slide, or overhead. Instead of spending an entire class period reviewing an exam, distribute solutions when the students hand-in their papers (this immediate feedback is also a great learning tool!). Hold students responsible for prerequisite material such as calculus, chemistry, dynamics; don't feel like you have to re-teach it to them.

Second, pay special attention to your textbook selection. The textbook should match your style and topic order as closely as possible. Example problems should be plentiful, well explained, and worked in good format. The text should be especially strong in areas that you intend for students to learn "on their own".

Consider holding exams and review sessions outside of class time while perhaps canceling one 1-hour class to compensate for a 2- or 3- hour exam. Note that this may be difficult to accomplish with a large class or with non-traditional students who have a full-time job or family obligations.

Use a variety of efficient classroom techniques that have been proven to be effective. For example, there are multiple pedagogies of engagement such as active/cooperative learning in the classroom, occasionally dividing the class into teams to work through multiple concepts together, interactive classroom techniques (e.g., dialogue, fill-in-the-blank hand-outs), and problem-based cooperative learning[2-6]. In addition, use hybrid classroom techniques[7] where parts of the course are web-based and/or electronically delivered. As a part of the hybrid technique, instructors can generate their own videos with supplemental lecture or topic details, worked examples, or demonstrations that can subsequently be loaded onto a course website. These hybrid materials could be used year-to-year with minimal revisions and downloaded by students for course support from the course website, such as Blackboard, currently used by LTU. Don't overlook films (NCFMF) and the CD or DVD that comes with the textbook (or, alternately, the publisher's website). Be aware that it will usually be necessary to assign these web-based/electronic items; students will usually not engage them on their own.

Use lots of paper handouts and/or post your Power Point slides or other lecture notes on your website or course-management software. Paper handouts will allow students to take notes on them during your presentation. If you employ these techniques, be certain that students don't "zone-out" during class, thinking that the handouts and web-posted slides/notes are sufficient without personal note-taking supplement.

When assigning homework, use several concept questions that require written English answers. Expect the answers to be well written in complete sentences and paragraphs.

Although in some instances a design project is eliminated to spend more time on fundamental concepts (as noted in the previous section), in other instances, course design projects can significantly supplement the learning process and can provide an understanding on how to integrate concepts presented in the course. At LTU, one instructor gives a design project to propose the major components with some analysis of a coal-fired power plant. This gives the student exposure to cycles, processes, components, efficiencies, and systems that are often lost in the study of discreet components in the course. If necessary, these projects can be assigned as team projects to reduce some of the individual student burden and to facilitate learning through student collaboration.

Finally, take advantage of common material between thermodynamics and fluid mechanics, especially if an instructor teaches both subjects. If not, it is extremely important that instructors of these two courses talk to each other. If possible, use common approaches and common notation for shared concepts such as mass conservation, control volume, and fluid properties. Possibly the best answer to the question posed by this paper, i.e., "Should thermodynamics and fluid mechanics be three or four credit hours?" is "Each should be three hours and there should be one extra hour that is common between them." It seems that at least one student who responded to the survey sensed this.

9. Conclusion

Many conclusions can be drawn from this study. When a three credit hour course has nearly identical objectives/outcomes to a four credit hour course, there are disadvantages for the student. When comparing course content, the four credit hour thermodynamics course covered two more topics with much needed extra time allotted for another topic. The three credit hour fluid mechanics course (18 fewer credit hours) had to cover more topics than the four credit hour course with obvious detrimental consequences. Student opinions are quite strong that four credit hours is appropriate and preferred for both courses. Common fluid mechanics exam problem scores indicate that students with more classroom hours get higher scores.

Because of these consequences, various options were explored for instructors that are allotted less than desirable credit hours, and proven recommendations are offered for effective/efficient material coverage that do not sacrifice student learning.

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