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# Study of Thermodynamics Syllabi as A Step Toward Understanding Second- and Third-Year Retention

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# Study of Thermodynamics Syllabi as A Step Toward Improving Second- and Third-Year Retention

Mechanical engineering is one of the largest and most versatile engineering disciplines, which offers graduates opportunities to work in fields that require basic engineering, energy conversion, energy resources, engineering and technology management, environment and transportation, manufacturing, materials and structures, and systems and design [1]. Retaining students to successful completion of their degree programs to support workforce development in these various fields is a priority for mechanical engineering programs.

An ASEE survey measured average persistence from the first to the second year of first time, full-time engineering students to be around 80% with a six-year graduation rate around 60% [2]. These results indicate an average of 20% of students leave in the first year with an additional 20% leaving in the second year and later. The long-term interest of the author is to increase graduation rates by focusing on why mechanical engineering students leave the program in the second year or later.

An important retention strategy for students is to develop their sense of belonging to a program by showing students that they are welcomed and supported – that the culture is inclusive [3], [4]. An earlier study confirms through survey findings that students' sense of belonging within an engineering program increase with time, which helps contribute to the 60% graduation rate [5]. Students' sense of belonging can be increased in many ways both inside and outside of the classroom. Students with a sense of belonging have greater awareness of student support services available to them and have engagement with academic advising, financial aid, and mental health services. These same students report a stronger sense of belonging when engaging with faculty who instruct using evidence-based teaching practices [6].

In addition to instruction using evidence-based pedagogy, another component of improving classroom instruction and a student's sense of belonging is through syllabus design. Parkes and Harris [7] argue one important role of a syllabus is to be learner-centered, focusing on the students and why they need to be effective learners. A syllabus may reflect the instructor's beliefs and attitudes about the subject matter and students, making it a guide for the instructor as well as to the students. Cullen and Harris argue that "a syllabus is more than an outline of course. It represents the mindset, that is the professor's philosophy of teaching and learning as well as his or her attitudes toward students, and conceptualization of the course [8]." Cullen and Harris further argue that a review of course syllabi can reveal much about an instructor's learner-centered practices and have developed a rubric for assessing learner-center qualities of course syllabi. Eslami, et al., analyzed undergraduate STEM syllabi and found students enrolled in courses with learner-center syllabi had a reduced opportunity gap, defined as the difference in grades earned by minoritized students and non-minoritized students in the examined STEM classes [9].

This paper offers a preliminary examination of the extent to which learning centered and belonging are messaged to engineering students through the study of twenty syllabi prepared for Thermodynamics. This course was selected because it is typically a required course, offered in the second year of a mechanical engineering program. The syllabi study is intended to serve as a starting point to discuss additional ways to increase second-year and third-year retention of mechanical engineering students by shifting focus to learner-centered practices.

**Study Methodology**

Texas state law, HB 2504, requires undergraduate syllabi be publicly available on public university websites [10]. The law makes it possible to collect syllabi from twenty institutions across the state for the first course in Thermodynamics from ABET-accredited mechanical engineering programs. Since the syllabi are required by law to be posted on institutional websites, they will first be examined to determine to extent to which they contain the essential elements of a syllabus. It is conceivable that faculty might post a skeletal syllabus to simply satisfy compliance with a state law.

There is not a single guiding document that defines the essential elements of a syllabus. To understand commonalities across higher education syllabi, Doolittle and Siudzinski conducted a literature review of 15 articles defining syllabi elements, developed syllabi categories based on this review, and finally examined 1000 higher-education syllabi to determine how the syllabi categories were populated [11]. They describe 26 syllabi components that fall within four broad categories: professor information, course information, grading information, and policy information. The first step in our study was to determine the extent to which the posted syllabi represented typical higher-education syllabi as described by the 26 syllabi components.

Subsequently, rubrics developed by Cullen and Harris [8] and modified by Eslami, et al. [9] were used to assess learner-centered qualities in the syllabi. The Cullen and Harris rubric was based on multiple studies of learning centered teaching and validated by brain function research. The rubric is divided into three categories: Community, Power and Control, and Evaluation / Assessment. Group work and team projects as well as opportunities for students to learn from each other are key elements of the Community category. Faculty accessibility can also foster a sense of community. The second category, Power and Control, focuses on whether the learning environment is shared by instructor and learner. The amount of choice given to students and responsibilities expected of a student as an indicator of a learner-centered environment are measured in this category. The more constructive Evaluation and Assessment (the third category) are used as feedback mechanisms, the more likely the environment is learner centered. The Cullen-Harris rubric uses a four-point scale (1 to 4) with 4 representing the most learner-centered.

Eslami, et al., [9], used the Cullen-Harris rubric to compare student outcomes with syllabi that were more or less learner-centered. Their interest built on research that showed minoritized students are often awarded lower grades than non-minoritized students in STEM class, which they referred to as an opportunity gap. Their study defined the opportunity gap as the difference in average grade-point-average (GPA) of minoritized students compared with non-minoritized students GPA for a particular class associated with a particular syllabus. Large opportunity gap refers to syllabi-GPA-course pairings in the 25$^{th}$ percentile of their study while the small opportunity gap referred to the 75$^{th}$ percentile as defined by difference in GPA for a particular syllabus-GPA-course pairing. Eslami, et al., [9] used a modified version of the Cullen-Harris rubric based on a five-point scale (0 to 4) where 0 indicates the information was not available in the syllabus which was used in this study as well.

Shown in Tables 1 through 3 are the rubrics for rating syllabi relative to learner centeredness using the tool developed by Cullen and Harris with the five-point scale use by Eslami, et al.

Table 1. Rubic for Rating Community.

| | |
|---|---|
| Accessibility of teacher | 0 Not stated |
| | 1 Available for prescribed number of office hours only; discourages interaction except in class or for emergency |
| | 2 Available for prescribed number of office hours; provides phone and email but discourages contact |
| | 3 Available for more than prescribed number of office hours; offers phone, email, fax, home phone; encourages interaction |
| | 4 Available for multiple office hours, multiple means of access including phone(s), email, fax; holds open hours in locations other than office (e.g. library or union); encourages interaction |
| Learning rationale | 0 Not stated |
| | 1 No rationale provided for assignments or activities |
| | 2 Explanation of assignments and activities but not tied directly to learning outcomes |
| | 3 Rationale provided for assignments and activities; tied to learning outcomes |
| | 4 Rationale provided for assignments, activities, methods, policies and procedures; tied to learning outcomes |
| Collaboration | 0 Not stated |
| | 1 Collaboration prohibited |
| | 2 Collaboration discouraged |
| | 3 Collaboration incorporated; use of groups for work and study |
| | 4 Collaboration required; use of groups for class work, team projects; encourages students to learn from one another |

Table 2. Rubic for Rating Power and Control.

| | |
|---|---|
| Teacher's Role | 0 Not stated |
| | 1 No shared power. Authoritarian, rules are written as directives; numerous penalties; no flexibility in interpretation; not accommodating to differences |
| | 2 No shared power; while teacher is ultimate authority, some flexibility is included for policies and procedures; some accommodation for differences among students |
| | 3 Limited shared power; students may be offered some choice in types of assignments or weight of assignments or due dates |
| | 4 Shared power. Teacher encourages students to participate in developing policies and procedures for class as well as input on trading, due dates and assignments. |
| Student's Role | 0 Not stated |
| | 1 Student is told what they are responsible for learning |
| | 2 Student is told what they are responsible for learning but encouraged to go beyond minimum to gain reward |
| | 3 Student is given responsibility for presenting material to class. Some projects rely on student's generated knowledge |
| | 4 Students take responsibility for bringing additional knowledge to class via class discussion or presentation |

| | |
|---|---|
| Outside Resources | 0 Not stated |
| | 1 No outside resources other than required textbook. Teacher is primary source of knowledge |
| | 2 Reference to outside resources provided but not required |
| | 3 Outside resources included with explanation that students are responsible for learning outside of the classroom and independent investigation |
| | 4 Outside resources included with explanation that students are responsible for learning outside of the classroom and independent investigation. Students expected to provide outside resource information for class |
| Syllabus Focus | 0 Not stated |
| | 1 Focus is on policies and procedures. No discussion of learning or outcomes |
| | 2 Weighted towards policy and procedures with some reference to content covered |
| | 3 Includes course objectives. Balance between policies and procedures and focus on learning |
| | 4 Syllabus weighted towards student learning outcomes and means of assessment; policies are minimal or left to class negotiation |

Table 3. Rubic for Rating Evaluation / Assessment.

| | |
|---|---|
| Grades | 0 Not stated |
| | 1 Focus is on losing points; grades used to penalize |
| | 2 Emphasizes the accumulation of points disassociated from learning performance |
| | 3 Grades are tied directly to learning outcomes; students have some options for achieving points |
| | 4 Grades are tied to learning outcomes; option for achieving points; not all work is graded |
| Feedback Mechanism | 0 Not stated |
| | 1 Midterm and final test grades only. Students not allowed to see or to retain copies of tests |
| | 2 Midterm and final test grades with minimal other graded work. Tests not cumulative. Students may see but not retain copies of tests |
| | 3 Grades are tied directly to learning outcomes; students have some options for achieving points |
| | 4 Grades are tied to learning outcomes; option for achieving points; not all work is graded |
| Evaluation | 0 Not stated |
| | 1 Tests (not comprehensive) |
| | 2 Tests, quizzes, and other summative evaluation |
| | 3 Summative and formative evaluation, written work required |
| | 4 Summative and formative evaluations including written and oral presentations, group work, self-evaluation and peer evaluation |

| | |
|---|---|
| Learning Outcomes | 0 Not stated |
| | 1 No outcomes stated |
| | 2 Goals for course stated but not in the form or learning outcomes |
| | 3 Learning outcomes clearly stated |
| | 4 Learning outcomes stated and are tied to specific assessments |
| Revision / Redoing | 0 Not stated |
| | 1 No rewriting or redoing of assignments allowed |
| | 2 Some rewriting or redoing of assignments allowed, but penalized |
| | 3 Rewriting and redoing of assignments allowed |
| | 4 Rewriting and redoing of assignments encouraged |

For this preliminary study all syllabi were scored by the author. The most current syllabi were found on the website mandated by state law and the most current syllabi were downloaded. No attempt was made to find syllabi based on a search of the instructor's website or the department website.

**Results**

In the following Figures 1 through 4, the syllabi components for the four major categories of Doolittle and Siudzinski [11] are presented on bar graphs to visually demonstrate the extent to which the twenty Thermodynamics syllabi contain many of the common elements of university syllabi.

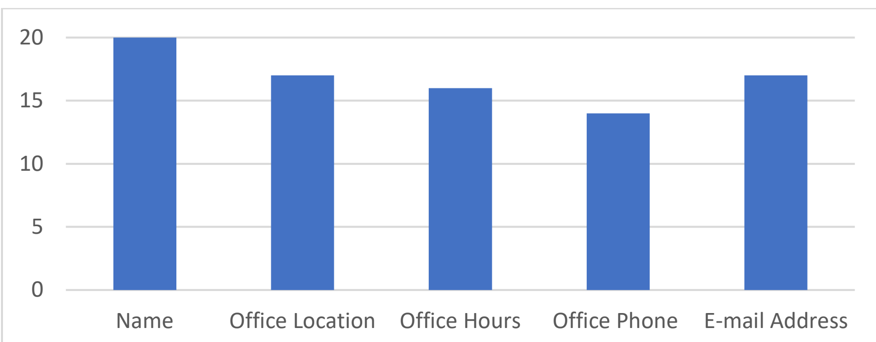


Figure 1: Instructor Information (Category Mean = 16.8).

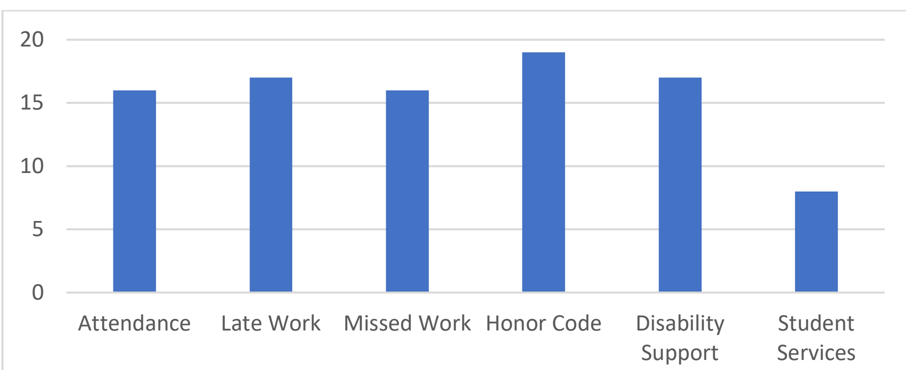


Figure 2: Course Policy Information (Category Mean = 15.5).

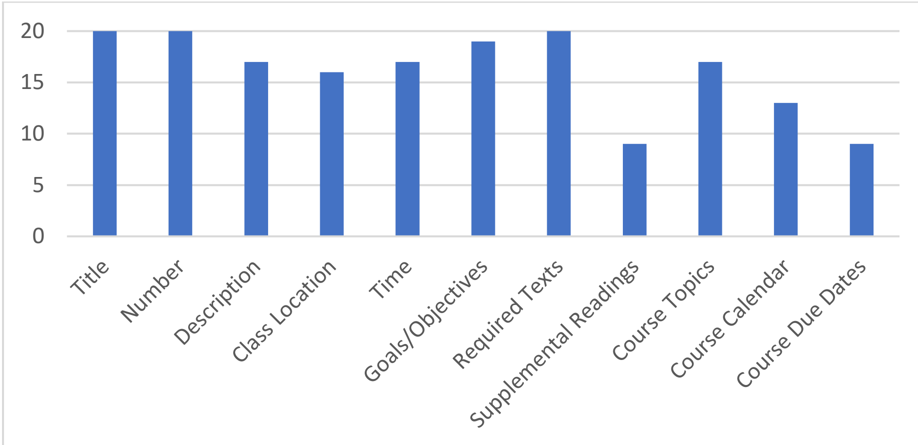

Figure 3: Course Information (Category Mean = 16.1).

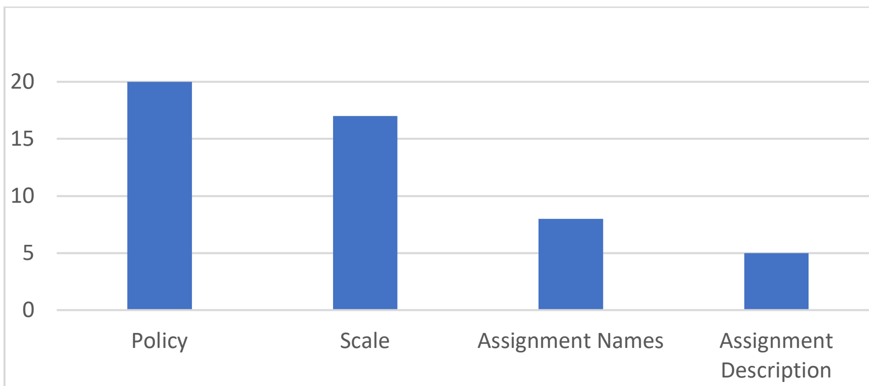

Figure 4: Grading Information (Category Mean = 12.5).

The mean for three of the four categories exceeded 75% indicating the majority of syllabi were representative of higher-education syllabi regarding Instructor Information, Course Policy Information and Course Information. All syllabi contained information on grading policies and the majority describing the grading scale. Only five of the syllabi had detailed assignment descriptions. The chapters covered in either of two textbooks were very similar across all syllabi. In addition to the categories described in [11], some syllabi contained the following items: campus carry policies, procedures in the event of extreme weather or an on-campus emergency, and copyright ownership of course materials. Overall, the analysis suggests the Thermodynamics syllabi contained enough information to be candidates for a preliminary rating of syllabi and measures of learner-centeredness.

The average rating and standard deviation for the rubrics presented in Tables 1 through 3 are shown below in Table 4. Also shown in the table are the results from Eslami, et al. [9]. For the current study no effort was made to gather GPAs from the ME Thermodynamics syllabi.

Table 4. Results of Thermodynamics Syllabi Study (Current Study) Showing Mean and Standard Deviation Compared with the Results of Eslami, et al. [9].

| Category | Item | Current Study Mean (Stand Dev) | Large Opportunity Gap [9] Mean (Stand Dev) | Small Opportunity Gap [9] Mean (Stand Dev) |
|---|---|---|---|---|
| Community | Accessibility of Teacher | 2.10 (0.89) | 1.83 (1.06) | 1.96 (1.06) |
| | Learning Rationale | 2.05 (0.67) | 2.13 (0.69) | 1.96 (0.52) |
| | Collaboration | 1.35 (1.24) | 1.74 (1.48) | 1.81 (1.75) |
| | | | | |
| Power & Control | Teacher's Role | 1.0 (0.0) | 1.57 (0.66) | 1.52 (0.70) |
| | Student's Role | 1.0 (0.0) | 1.22 (0.52) | 1.81 (0.96) |
| | Outside Resources | 1.25 (0.43) | 1.70 (0.82) | 2.15 (1.13) |
| | Syllabus Focus | 2.15 (0.57) | 1.83 (0.83) | 2.30 (0.95) |
| | | | | |
| Evaluation / Assessment | Grades | 2.00 (0.0) | 2.00 (0.43) | 2.04 (0.71) |
| | Feedback Mechanism | 1.90 (0.30) | 2.30 (0.47) | 2.30 (1.07) |
| | Evaluation | 2.00 (0.0) | 2.70 (0.47) | 2.89 (0.93) |
| | Learning Outcomes | 2.70 (0.56) | 2.04 (0.98) | 2.22 (0.89) |
| | Revision / Redoing | 0.0 (0.0) | 0.78 (0.80) | 1.07 (0.92) |

One of the more interesting findings of this study is that the ratings for learner-centered syllabi were lower than 2.0 except for one case. This finding aligns with that of Eslami, et al. suggesting that STEM courses, and Thermodynamics courses in particular, are more instructor centered. Both studies show ratings in the category of Power and Control to be the lowest, reinforcing the notion of an authoritarian instructor with students told what they are responsible for learning. The limited use of outside resources beyond the required textbook is also prevalent. Based on the Cullen and Harris rubric, one suggestion to provide learners with more "power and control" over their classroom experience is to encourage them to find outside resources that support their learning as part of their responsibilities for learning outside the classroom. There are numerous YouTube videos and freely available websites developed to help students learn Thermodynamics. Perhaps one assignment in the class might ask students to find and share such outside resource information for class.

The lowest rated item in the study was "Revision and Redoing" in the Evaluation and Assessment category. For the highest learner-centered rating, the rubric is mapped to "rewriting and redoing of assignments encourage". Perhaps this is difficult to achieve in many STEM courses and in Thermodynamics where writing and rewriting are often not part of the learning experience. To move toward a more learner-centered experience, it may be possible to allow students to redo major assignments, perhaps even retake examinations to improve their score. It may be the case this occurs more often than noted in the mandatory-posted syllabus. In a learner-centered environment, the focus is on achieving learning outcomes and retaking an exam or quiz might help students achieve the desired outcomes.

The item “Evaluation” in the Evaluation and Assessment category received relatively high ratings in this study and in Eslami’s study. The evaluations appear to mostly include tests, quizzes, and other summative evaluations. To move toward a more learner-centered environment, it may be easy to add group work, or self-evaluation, or peer-evaluation to help students think about their own learning.

In the category of Community, accessibility of the instructor is primarily through prescribed office hours. All examined syllabi provided office hours followed by days and times. About half of the syllabi included opportunities for students to contact their instructor outside of office hours via e-mail, Zoom, or appointment. One syllabus included language that explained the importance of office hours, encourage students to “please take advantage of office hours.” One suggestion to encourage more learner-centric experiences through the syllabus is to include language encouraging students to contact the instructor or teaching assistant for help. “Meet with me” could offer a supportive message that subtly, but importantly, changes the tone of the syllabus.

**Conclusions**

An important retention strategy for students is to develop their sense of belonging to a program by showing students that they are welcomed and supported. Developing strategies for more learner-centered instruction improves classroom outcomes and a student’s sense of belonging. This paper is based on the idea that syllabus content is a measure of the instructor’s conceptual design of the course where they build in learner-centered practices. The study is preliminary, utilizing syllabi from a course taken by most mechanical engineering students in their second year and readily available on the internet. Next steps include having a team of reviewers analyze syllabi rather than a single reviewer. An additional next step is to have a deeper look at instructor syllabi development practices and the extent to which they mirror mechanical engineering faculty’s conceptualization of the course. It would also be valuable to build on the work of Eslami, et al., to study the relationships between learner-centric syllabi elements and student performance in the classroom.

Additional studies could include asking students about syllabus elements most important to their sense of belonging in the course. A further student study could examine the overall readability of the syllabus from a student perspective and what elements of a syllabus are of most importance to them.

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