Intentional Use of the Learning Management System: A Case Study in Self-Regulatory Behaviors in a Blended Undergraduate Thermodynamics Course

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Abstract

In a blended undergraduate thermodynamics course, affordances within a learning management system (LMS) were used to highlight student learning outcomes, require foundational course content to be completed before attempting more complex topics, provide mastery-oriented feedback, allow students to track their progress, and promote metacognitive reflection. This paper describes the use of these options within the Canvas LMS. Additionally, this study investigated whether student self-regulatory behaviors changed during the course. Students were asked to complete a survey about their metacognitive self-regulatory activities related to studying for this course. The first survey was completed during the fifth week of the course, after most students had completed two reflection assignments. The same survey questions were administered a second time, during the final two weeks of the course. Survey results suggest some increase in student self-regulatory behaviors during the course. These results suggest that, near the end of the course, students were more likely to set study goals for themselves.

Introduction

Self-regulated learning refers to how students control their own learning [1], [2]. Pintrich describes a framework for self-regulated learning based on four areas of regulation (cognition, motivation, behavior, and context) and four phases of regulation (planning, monitoring, control, and reflection) [3]. The planning phase includes setting goals and planning time and effort. Goal setting has been shown to increase academic performance [4]. Monitoring involves awareness and self-observation of behavior. The control phase includes choosing strategies and deciding when to seek help. Reflection involves evaluating the task and behavior. Metacognition, broadly described as thinking about thinking, is a component of self-regulation. Metacognitive assignments can help students be more self-directed. Tanner provides several example prompts for incorporating metacognition into regularly scheduled course activities [5].

Previous studies indicate a need to encourage self-regulated learning in students in higher education courses [6], [7]. Promotion of self-regulatory behavior has been shown to increase student course performance [8], [9]. Fully online or blended learning may require a greater degree of self-direction from a student. Therefore, in online course environments, it is even more important to provide support such as scaffolding of large assignments or giving students opportunities to reflect on their learning [10]. Intentional use of learning management system (LMS) tools and features can help students self-regulate their learning [11]–[13].

This case study involves an undergraduate thermodynamics course in a mechanical engineering curriculum, typically taken in the first semester of the second year in the program. The prerequisite course is calculus-based physics, and co-requisites include multivariate calculus and general chemistry. The course is a prerequisite for upper-level mechanical engineering courses. The course was offered in a blended format with 110-minute face-to-face on-campus class sessions approximately once every two weeks during a 16-week semester.

This study investigated whether student self-regulatory behaviors would change during a course that emphasized learning outcomes and required reflection assignments. Additionally, this paper will describe use of the Canvas LMS to encourage self-regulatory behaviors.

Pedagogical Approach

Self-regulatory behaviors were encouraged in this course through an emphasis on learning outcomes, opportunities for reflection, mastery-oriented feedback, and intentional organization and sequencing of course material. Features of the Canvas LMS were chosen to support these strategies.

Student learning outcomes were emphasized in all assignments and class activities. The course was planned using backward design, in which the learning outcomes for the course are determined first [14]. Then assessments aligned with the learning outcomes are determined. Finally, other assignments, class activities, and readings and materials, which support the learning outcomes, are selected. The Quality Matters Higher Education Rubric and other guidelines for online course development also emphasize associating each activity or assignment with the corresponding learning outcomes and making those clear to the students, to help them see the purpose of assignments. In this course, student learning outcomes were set by the mechanical engineering program, and the instructor-written module outcomes (Appendix A) were from the student perspective, were measurable, and stated why the student needed to achieve the outcome [15]. A list of the course modules is given in Table 1.

Table 1. Course modules

Module	Topic
1	Introduction
2	Thermodynamic Properties
3	First Law of Thermodynamics
4	Second Law of Thermodynamics
5	Vapor Power Systems
6	Gas Power Systems
7	Refrigeration and Heat Pump Systems

The course used a flipped learning model, where the direct instruction that traditionally occurs in the group learning space is moved to the individual learning space, and in the group learning space, students interact with each other and the instructor to apply concepts [16]. Guided practice assignments were meant to prepare students in a flipped learning environment for the group activities [17], [18]. Each guided practice assignment included an overview to put the assignment in context with previous or future topics, a list of associated learning outcomes, resources such as readings and videos, an assignment, and instructions for submitting the assignment. The learning outcomes were separated into two sections, basic learning outcomes that were expected to be completed prior to group activities, and advanced learning outcomes that were expected to be completed later through participating in that module's activities and through individual practice. Intentionally structured flipped learning environments can encourage self-regulated learning. Due to the emphasis on the individual's responsibility for learning, students have the opportunity to practice all four phases (planning, monitoring, control, and reflection) of self-regulation in guided practice assignments, and later in group activities [17]. For an example of a guided practice assignment in this course, see Appendix B.

Metacognitive reflection was encouraged by including a reflection prompt at the end of each module. These informal assignments asked students to choose from a list of questions and respond about their study behaviors or goals, or to identify important concepts from the module. The following is an example reflection prompt:

> *Think about the work you have completed in Module 2. Answer any or all of the following questions.*
>
> - *What is the most important thing you learned in this module?*
> - *What was challenging about this module?*
> - *What learning strategies worked for you?*
> - *Will you need to make any changes for the next few weeks?*

A submission for the module's reflection assignment was required to complete the module, as described later in this section. In some cases, the reflection assignment was required to be submitted before the student could access the online quiz for that module.

Course grades were determined using specifications (or specs) grading, a relatively new grading method structured around the completion of pre-determined "bundles" of assignments instead of using points or weighted averages [19]. Students are given detailed requirements or specifications for a successfully completed assignment, and student work is graded pass/fail based on whether the requirements were met. Letter grade requirements for this course are shown in Table 2. The outcomes associated with the core quizzes are indicated in Appendix A. "Plus" or "minus" modifications to letter grades, such as "B+", were determined based on the number of smaller assignments completed. The instructor's previous implementation of specs grading in this course has been described elsewhere [20]. Students had opportunities to reattempt assessments that were not passed on the first attempt. Mastery-oriented feedback provided by the instructor focused on achievement of a standard and indicated correct and incorrect portions of the proposed solution.

Table 2. Course grade requirements

To earn this grade:	Accomplish the following:
A	Earn “Pass” scores on all 9 core quizzes and earn “Pass” scores on 6 additional quizzes.
B	Earn “Pass” scores on all 9 core quizzes and earn “Pass” scores on 4 additional quizzes.
C	Earn “Pass” scores on all 9 core quizzes.
D	Earn “Pass” scores on any 7 core quizzes.

To implement the strategies above, certain features of the Canvas LMS were intentionally used. All course material and assignments were organized within the module functionality. The requirement and prerequisite options within each module were used to specify what a student needed to achieve to complete a module and access a subsequent module. Frequently used requirements were “view” for overview and content pages and “submit” for assignments. Because the material in the final third of the course extended from earlier course topics, some quizzes had the requirement of “score at least” a minimum number of points. Modules early in the course had a prerequisite to complete the previous module. For modules later in the course, specific modules from earlier in the course were prerequisites. The instructor view for one module is given in Figure 1. For this module, the modules containing a reflection and quizzes from earlier in the course were set as prerequisites. Three content pages were required to be viewed, and two assignments were required to be submitted. The student view of the module was similar but included visual indications of which requirements had been completed. A green check mark appeared next to a completed requirement, and requirements not yet completed had an open circle next to them. An orange dash icon appeared next to overdue assignments.

Several modules included one or more no-stakes formative assessment checks that students could attempt as many times as they wished. These typically involved multiple choice questions or problems with numerical solutions. Custom feedback was provided based on whether the response was correct or incorrect. These assignments were not graded, but students had to at least view the assignment to complete the module requirements.

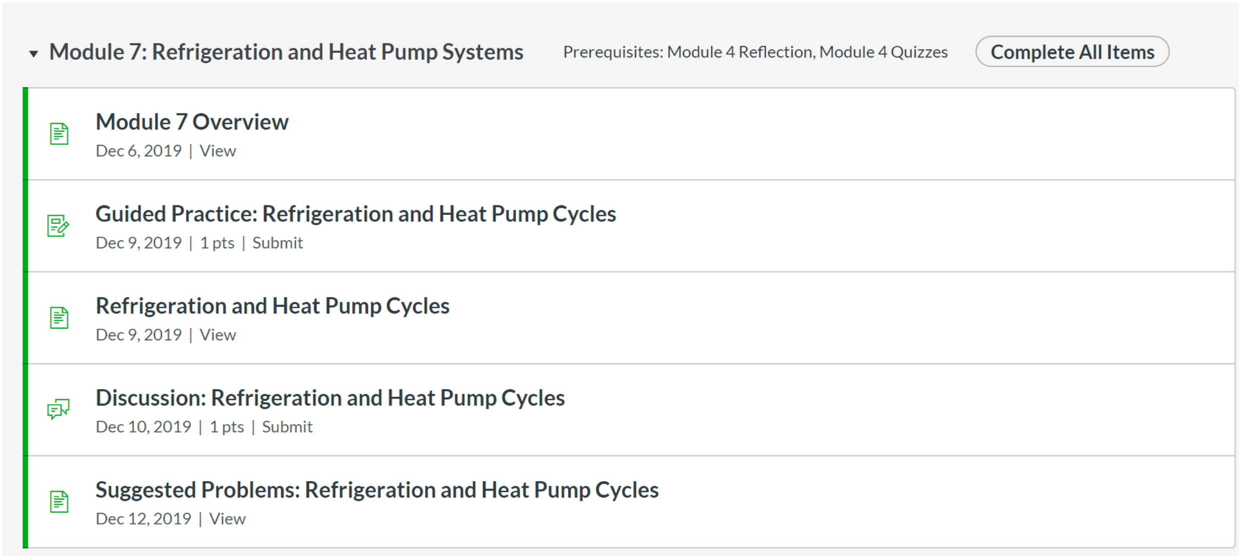

Figure 1. Example module requirements in Canvas. Prerequisites for this module included a reflection and quizzes from earlier in the course. Content pages were required to be viewed, and assignments were required to be submitted.

One challenge of using specs grading is having a convenient way for students to track their course grade when many LMS gradebooks rely on points and percentages. An outcome and associated rubric were created for each assignment/assessment that counted toward the course grade. The outcomes were grouped by assignment type (core quizzes, additional quizzes, guided practice, and participation). In Canvas, the Learning Mastery Gradebook feature was enabled for instructor and students. This gradebook option shows how many outcomes in each group that a student has mastered. This allows students to check their progress toward a desired course grade without an additional spreadsheet or checklist. The student view of the Learning Mastery Gradebook at the start of the course is given in Figure 2. Each category of outcomes could be expanded to show all outcomes, those that had been mastered, and the assignment associated with each outcome. Because the traditional gradebook view was the default and could not be disabled, assignment-level grading schemes of "Pass"/"No Pass" were used for assignment scores, and individual assignment options were set to display each assignment score as a letter grade (either "Pass" or "No Pass"). Percentage totals were hidden in student grade summaries in the traditional gradebook view.

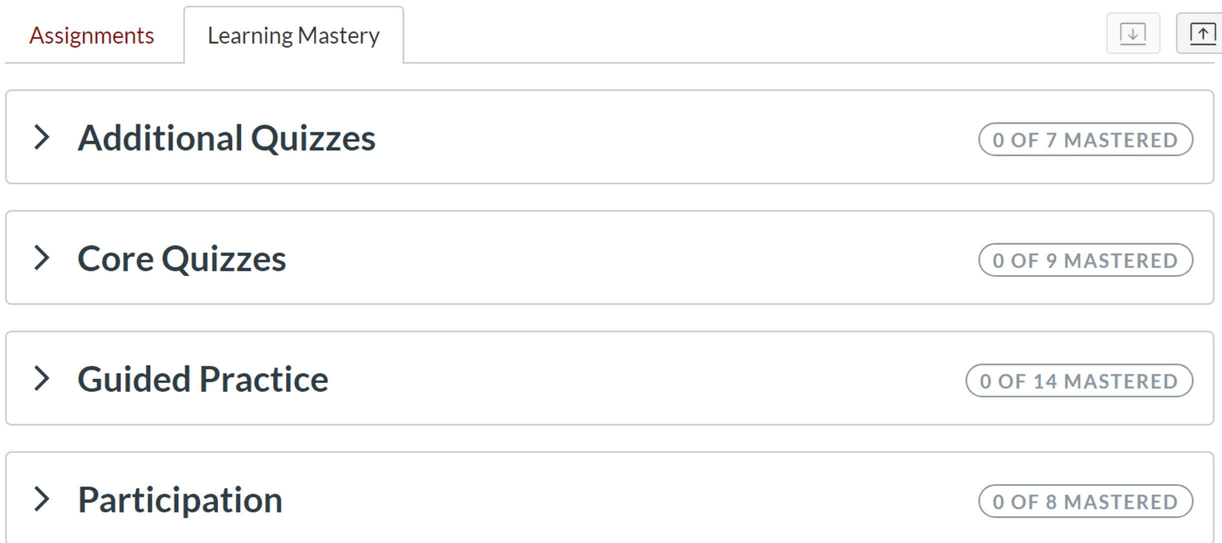

Figure 2. Student view of Learning Mastery Gradebook in Canvas. Expanding each category shows all its outcomes, which outcomes have been mastered, and the assignment associated with each outcome.

Survey Methodology

This study investigated whether student self-regulatory behaviors would change during a course that emphasized learning outcomes and required reflection assignments. The Motivated Strategies for Learning Questionnaire (MSLQ) is a validated self-report instrument with fifteen different scales with a total of 81 items for assessing students' motivation and learning strategies for a college course [21]. The metacognitive self-regulation scale ($\alpha = 0.79$, 12 items) was used in this study. The questions in this scale covered three general processes of metacognitive self-regulation: planning, monitoring, and regulating. Responses were made on a 7-point scale of 1 (not at all true of me) to 7 (very true of me). The same survey was administered twice to a class of 15 students, once during week 5 and again during week 14 of the 16-week semester. The surveys were completed during class on paper and were completed anonymously. For the 2-sample *t*-test, significance was set at 0.05.

Results and Discussion

The guided practice assignments were meant to prepare students for the group activities online and during the on-campus class sessions. These assignments, along with other small assignments, were used to determine "plus" or "minus" modifications to letter grades, such as "C-." Figure 3 gives a summary of the number of these assignments that were submitted. Sixty percent of the students in the course submitted at least 12 of the 14 guided practice assignments. The remaining students each submitted between 1 and 8 of these assignments.

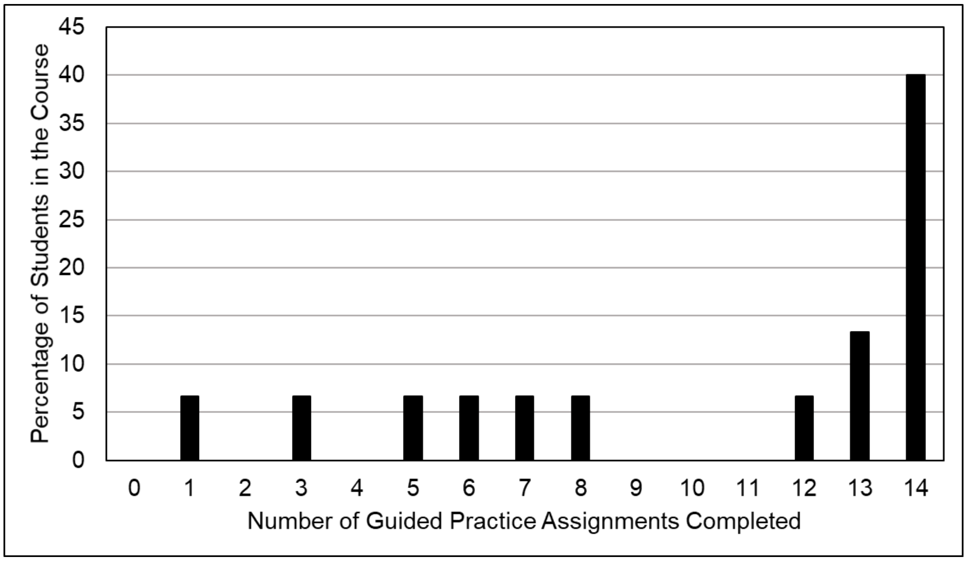

Figure 3. Number of guided practice assignments completed.

The reflection assignments did not count toward the course grade but had to be submitted for the module to be considered complete. As shown in Figure 4, over 50% of the students in the course completed all seven reflection assignments. Based on the number of guided practice and reflection assignments completed, approximately 50-60% of the students were regularly completing the types of assignments that most required practice of metacognitive skills.

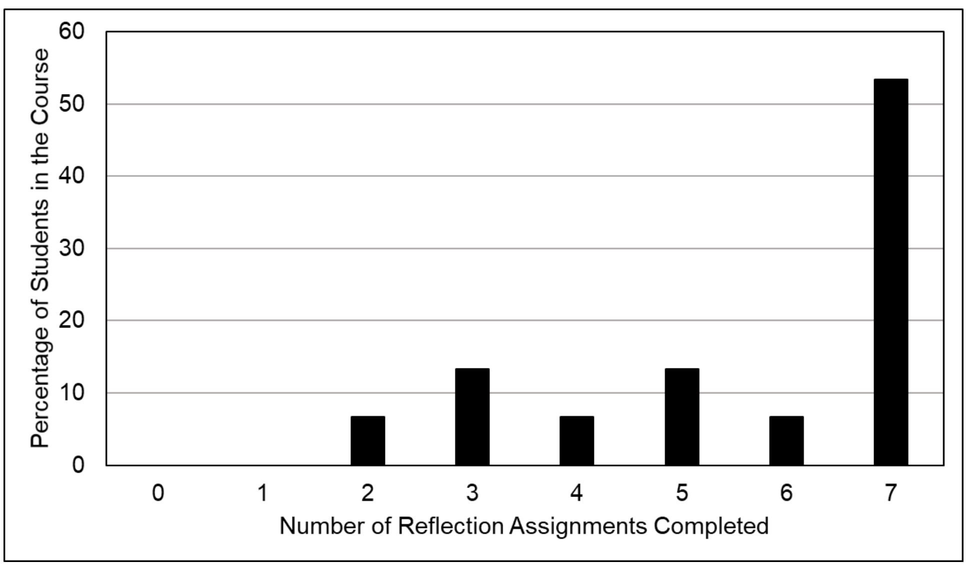

Figure 4. Number of reflection assignments completed.

Fifteen students (100% response rate) completed the survey on metacognitive self-regulation in week 5, and 12 students (80% response rate) completed the survey in week 14. Response summaries in the form of box plots for each of the 12 survey items are given in Figures 5-16, with values reported to 95% confidence. One instance where one survey item was left blank during the first administration of the survey is indicated in Figure 11.

Figures 5-8 refer to survey items associated with the planning phase of regulation. As shown in Figure 5, a similar distribution of responses was given early in the course and near the end of the course to the following survey item: “During class time I often miss important points because I’m thinking of other things.”

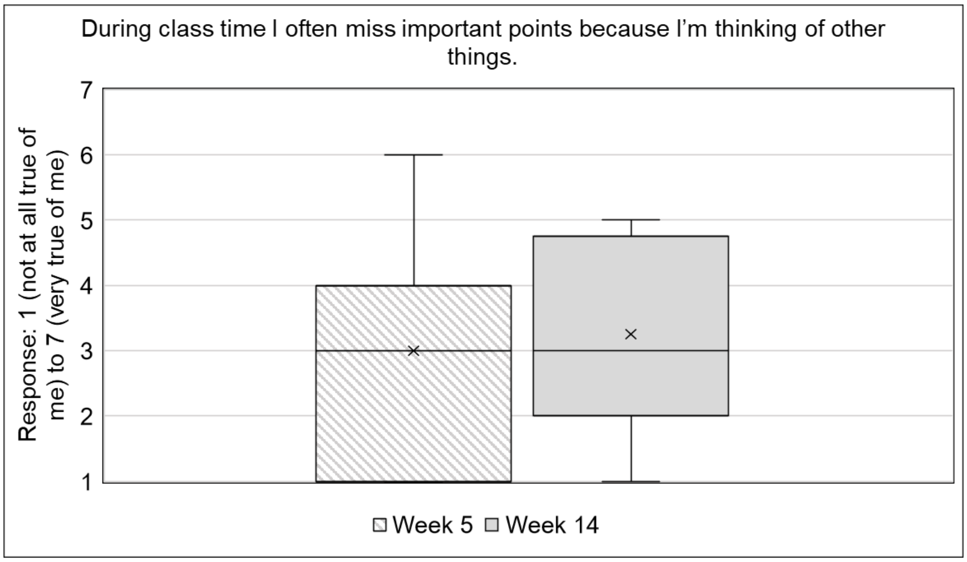

Figure 5. Summary of responses to “During class time I often miss important points because I’m thinking of other things.” Week 5: 3.00 ± 0.89 (95%), Week 14: 3.25 ± 0.86 (95%), $p = 0.665$.

There was no significant difference in the response to the following survey item: “Before I study new course material thoroughly, I often skim it to see how it is organized,” as shown in Figure 6.

As shown in Figure 7 there was no significant change in how students responded to the following item: “I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.”

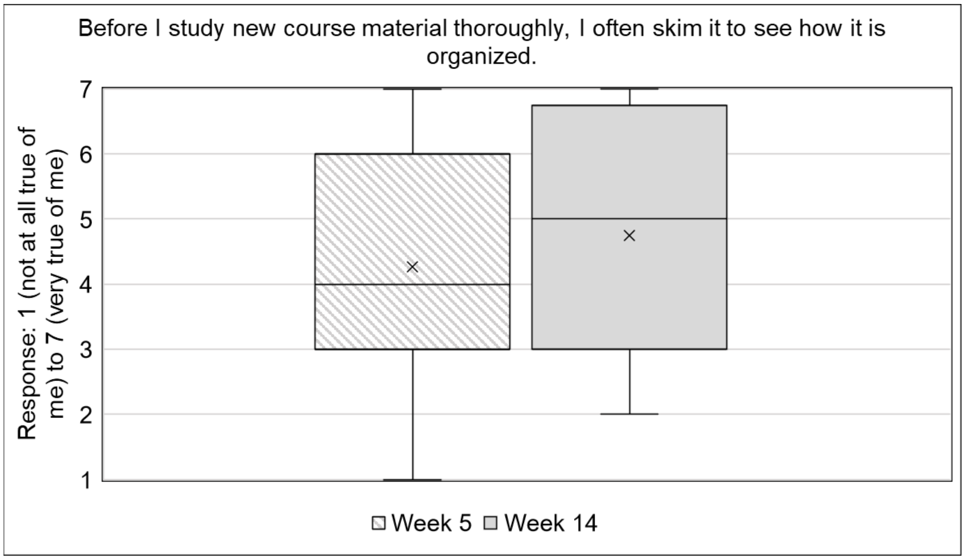

Figure 6. Summary of responses to "Before I study new course material thoroughly, I often skim it to see how it is organized." Week 5: 4.27 ± 1.01 (95%), Week 14: 4.75 ± 1.25 (95%), $p = 0.519$.

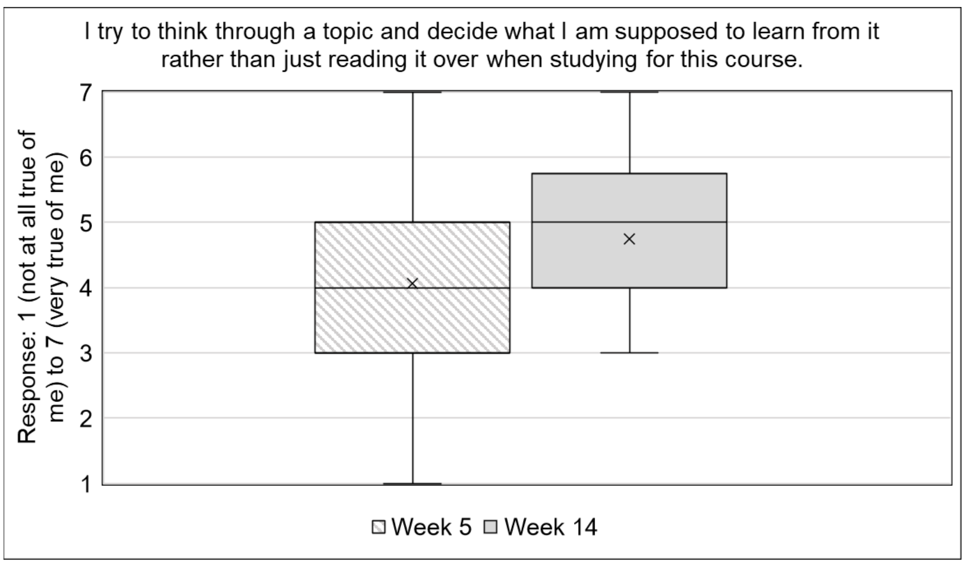

Figure 7. Summary of responses to "I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course." Week 5: 4.07 ± 0.80 (95%), Week 14: 4.75 ± 0.77 (95%), $p = 0.193$.

As shown in Figure 8, a significant ($p < 0.05$) difference was found for the following item: "When I study for this class, I set goals for myself in order to direct my activities in each study period." These results suggest an increase in student planning behaviors. The students in this course may have been more likely to take ownership of their own learning. The emphasis on course learning outcomes and assignment outcomes may have aided in students setting their own goals.

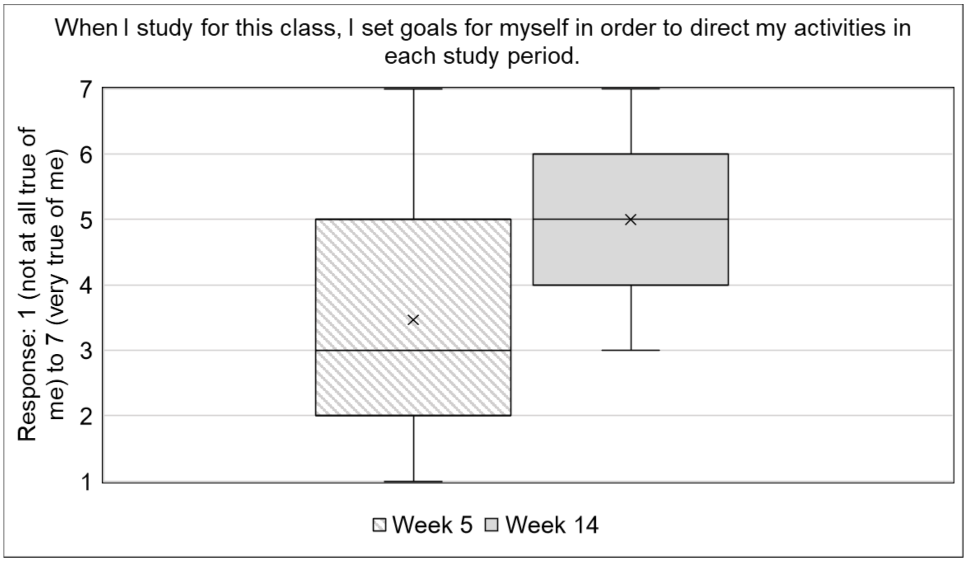

Figure 8. Summary of responses to "When I study for this class, I set goals for myself in order to direct my activities in each study period." Week 5: 3.47 ± 1.02 (95%), Week 14: 5.00 ± 0.86 (95%), $p = 0.020$.

Figures 9-12 refer to survey items associated with the monitoring phase of regulation. Near the end of the course, the range of answers given in response to "When reading for this course, I make up questions to help focus my reading" increased compared to early in the course, as shown in Figure 9. However, no student gave a response higher than 4.

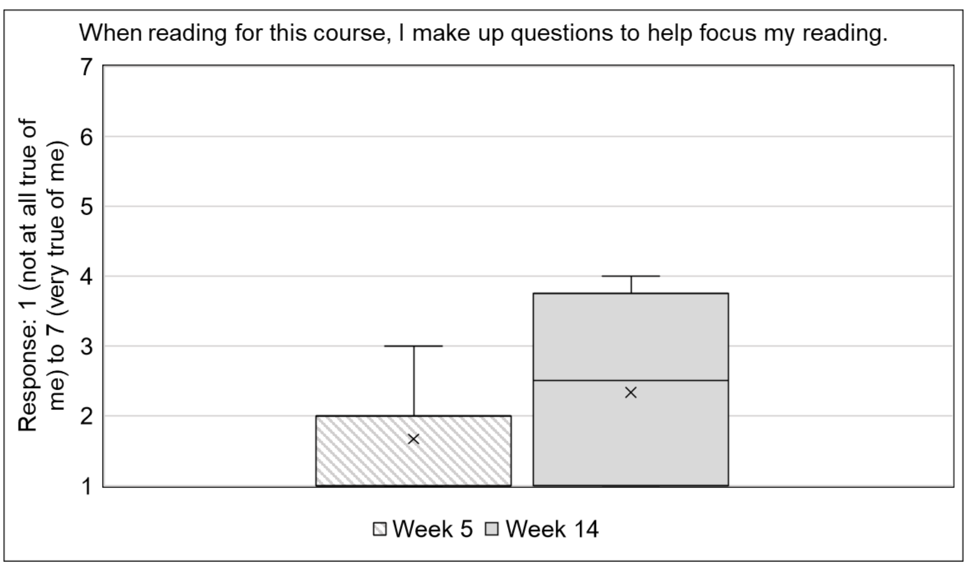

Figure 9. Summary of responses to "When reading for this course, I make up questions to help focus my reading." Week 5: 1.67 ± 0.45 (95%), Week 14: 2.33 ± 0.83 (95%), $p = 0.140$.

As shown in Figure 10, most students did not strongly agree or disagree with the following statement: "I ask myself questions to make sure I understand the material I have been studying in this class." Similar results were reported early in the course and near the end of the course.

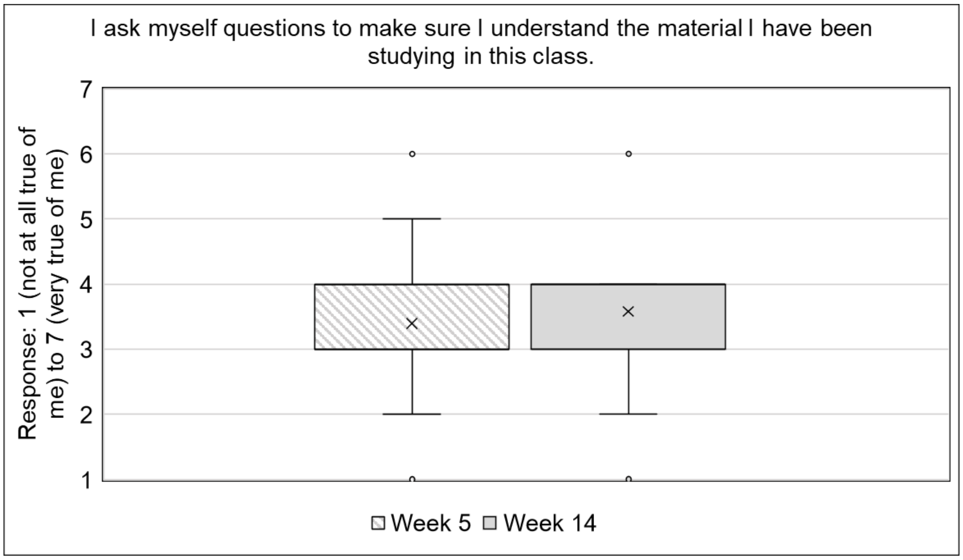

Figure 10. Summary of responses to "I ask myself questions to make sure I understand the material I have been studying in this class." Week 5: 3.40 ± 0.78 (95%), Week 14: 3.58 ± 0.79 (95%), $p = 0.722$.

As shown in Figure 11, a significant ($p < 0.05$) difference was found for the following survey item: "I often find that I have been reading for this class but don't know what it was all about." Without additional information, it is unclear whether this indicates a decrease in monitoring behavior, or an increase in difficulty of course readings. Two other survey items related to reading showed a decrease in agreement, but the difference between the end and beginning of the course was not significant (Figures 13 and 14). It may be that students found the course readings more difficult toward the end of the course; this material required synthesis and application of previous course concepts. Additionally, students may be busier toward the end of the semester with projects and exams in other courses which may compete for their study time.

As shown in Figure 12, there was no significant change in how students responded to the following item: "When studying for this course I try to determine which concepts I don't understand well."

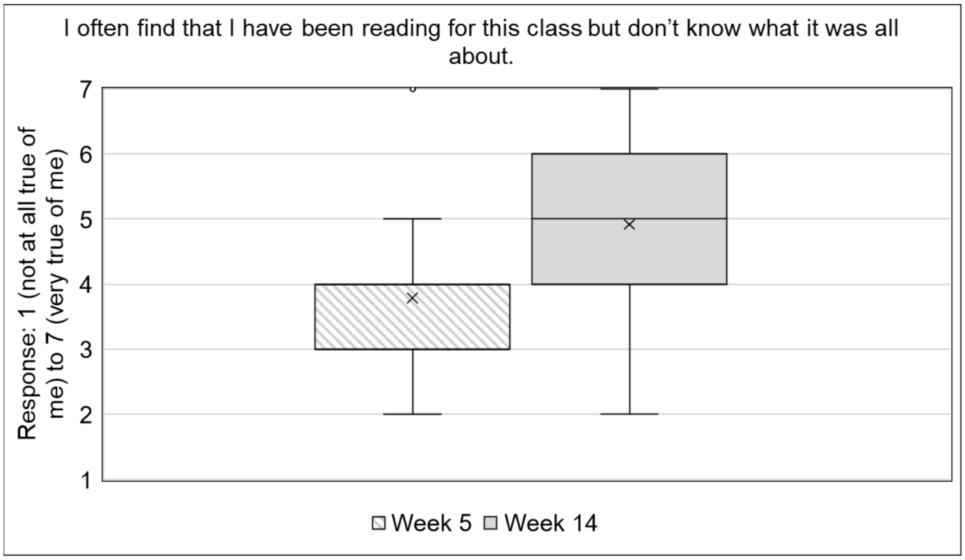

Figure 11. Summary of responses to "I often find that I have been reading for this class but don't know what it was all about." Week 5 (n = 14): 3.79 ± 0.72 (95%), Week 14: 4.92 ± 0.88 (95%), p = 0.040.

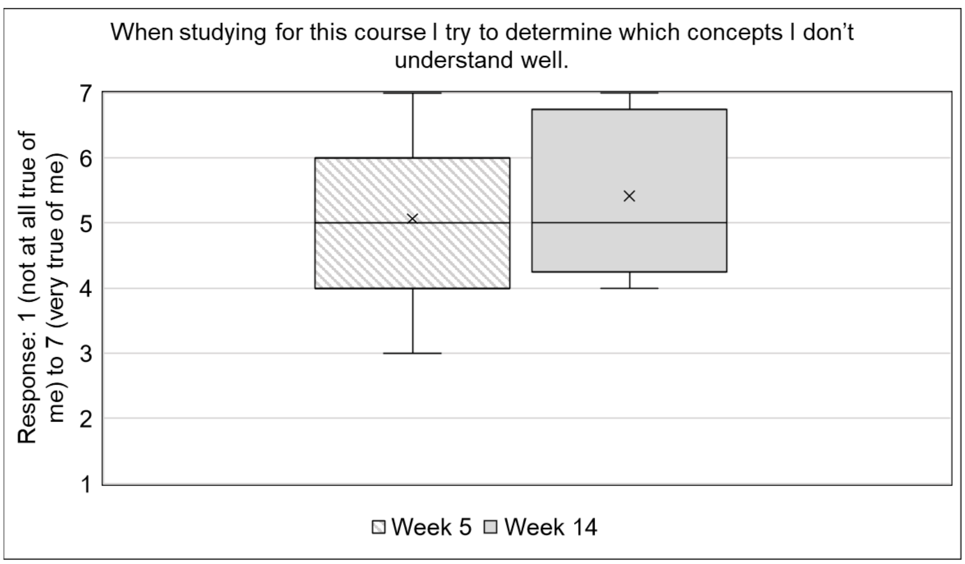

Figure 12. Summary of responses to "When studying for this course I try to determine which concepts I don't understand well." Week 5: 5.07 ± 0.64 (95%), Week 14: 5.42 ± 0.74 (95%), p = 0.445.

Figures 13-16 refer to survey items associated with regulating activities. The responses in Figure 13 indicate that there was no significant change in students' agreement with the following statement: "When I become confused about something I'm reading for this class, I go back and try to figure it out."

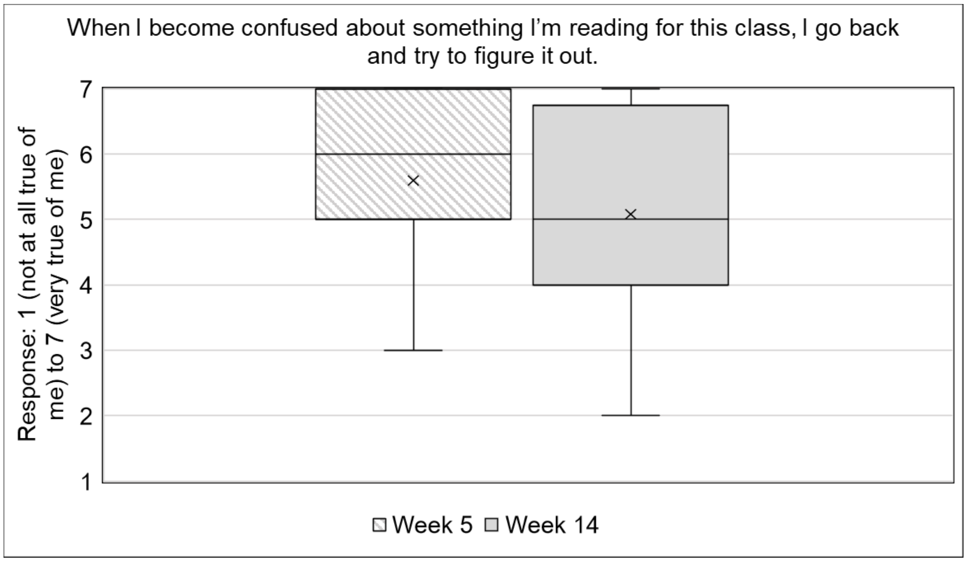

Figure 13. Summary of responses to "When I become confused about something I'm reading for this class, I go back and try to figure it out." Week 5: 5.60 ± 0.72 (95%), Week 14: 5.08 ± 1.03 (95%), $p = 0.380$.

The results in Figure 14 also suggest that students did not change their behavior in reading course material. There was no significant difference in the responses to "If course readings are difficult to understand, I change the way I read the material" near the end of the course.

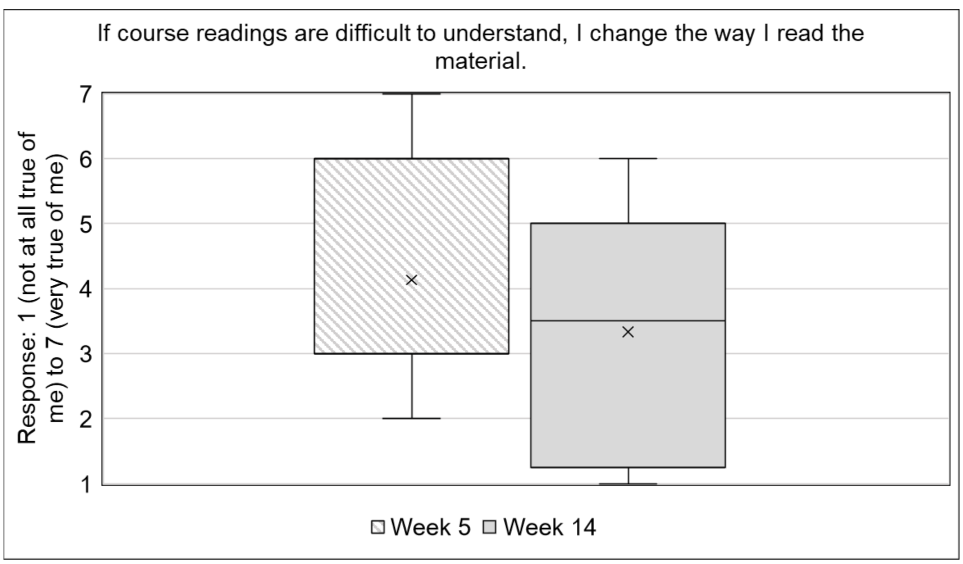

Figure 14. Summary of responses to "If course readings are difficult to understand, I change the way I read the material." Week 5: 4.13 ± 0.91 (95%), Week 14: 3.33 ± 1.13 (95%), $p = 0.241$.

Near the end of the course, more students agreed with "I try to change the way I study in order to fit the course requirements and the instructor's teaching style," as shown in Figure 15. Knowing that certain course material was required to be mastered to pass the course may have an effect on how students study. Decisions about studying may also have been influenced by having the option to reattempt assessments on previous material instead of receiving partial credit and moving on to new content.

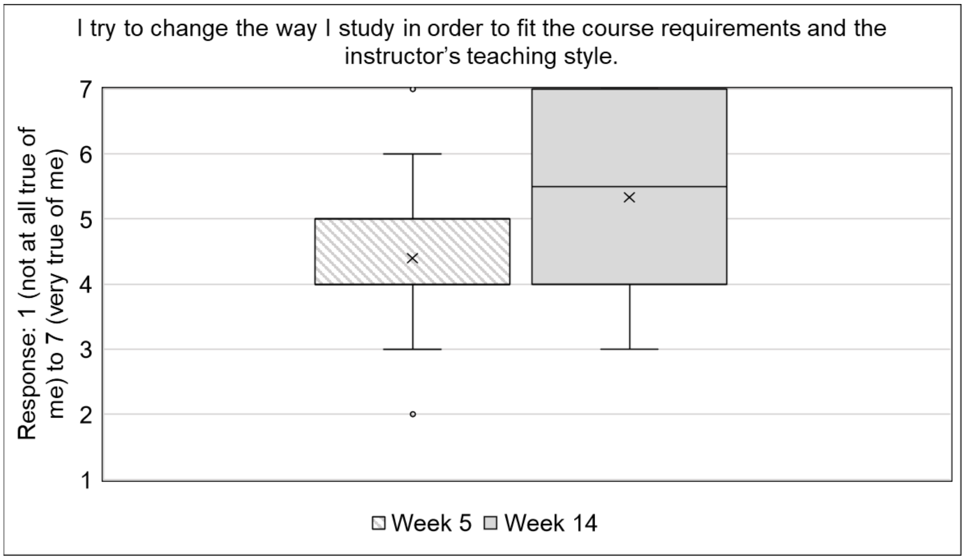

Figure 15. Summary of responses to "I try to change the way I study in order to fit the course requirements and the instructor's teaching style." Week 5: 4.40 ± 0.69 (95%), Week 14: 5.33 ± 0.95 (95%), $p = 0.097$.

No significant difference was found in the response to "If I get confused taking notes in class, I make sure to sort it out afterwards," as shown in Figure 16.

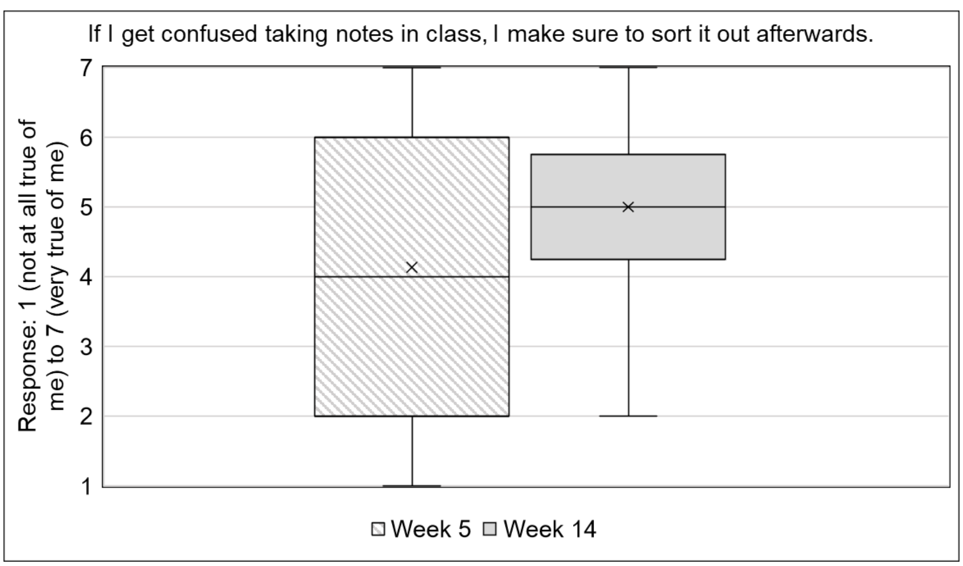

Figure 16. Summary of responses to "If I get confused taking notes in class, I make sure to sort it out afterwards." Week 5: 4.13 ± 1.06 (95%), Week 14: 5.00 ± 0.86 (95%), $p = 0.182$.

Strategies incorporated in this course are applicable to other disciplines and course levels. Additionally, nearly all the strategies described in this paper could be used to support a fully face-to-face course. Reflection assignments may be assigned for homework or completed during class time. Emphasizing learning outcomes is important for any course modality. Low-stakes formative assessments can be assigned for homework or can be done using only a few minutes of class time [22].

Several limitations exist for this study. This study considers a single offering of a course with an enrollment of 15 students. The first survey was administered during the fifth week of the course, after most students had completed two reflection assignments. No qualitative survey data were collected. This study did not account for other factors outside the course, such as other courses and other demands on student time, which may have influenced student study behaviors. Future work may include increasing the sample size and studying other courses. Additionally, the change in individual participant survey responses should be determined to better understand the change in self-regulatory behavior. Qualitative data should be gathered to complement the quantitative data. The first survey should be administered earlier in the course, prior to completing reflection assignments.

Conclusion

Features of the Canvas LMS were used to promote self-regulated learning. Guided practice assignments were used to introduce each course topic, learning outcomes were emphasized for each assignment/activity, the requirement and prerequisite options for Canvas modules were used to require foundational content to be completed before advanced topics, and a reflection assignment was required to be submitted to continue to the next module. Mastery-oriented feedback was provided through specs grading, and the Canvas Learning Mastery Gradebook feature was used to aid students in keeping track of course grades. Survey results suggest some increase in self-regulatory behaviors, but additional research is needed, especially pertaining to student reading habits and reading comprehension in this course.

Appendix A

Module Outcomes

- I can explain the concepts of equilibrium, temperature, property, state, and thermodynamic system to appropriately use these terms to describe scenarios and solve problems.*
- I can determine the difference between closed systems and open systems in order to analyze both types of systems.*
- I can determine thermodynamic properties of pure substances in two phases or in a single phase in order to use these properties to solve problems.*
- I can evaluate expansion or compression work in order to solve more complex problems involving closed systems or thermodynamic cycles.*
- I can state the first law of thermodynamics and explain each term in the equation for closed systems in order to analyze these systems.*
- I can apply the first law of thermodynamics to closed systems to solve problems related to common engineering systems.*

- I can explain each term in the first law equation for open systems in order to analyze these systems.*
- I can apply the first law of thermodynamics to open systems at steady state to solve problems related to common engineering systems.*
- I can apply the first law of thermodynamics to open systems that are not at steady state to solve problems related to common engineering systems.
- I can state the second law of thermodynamics and explain its significance in order to analyze common engineering systems.*
- I can evaluate the performance of power cycles and refrigeration and heat pump cycles using corollaries of the second law of thermodynamics in order to analyze all processes in these types of cycles.
- I can apply the concept of entropy to closed and open systems in order to compare actual system behavior with idealized, reversible behavior.
- I can analyze all processes in a vapor power system in order to calculate its performance.
- I can analyze all processes in an Otto, Diesel, or dual cycle in order to calculate its performance.
- I can analyze all processes in a gas turbine power system in order to calculate its performance.
- I can analyze all processes in a refrigeration or heat pump system in order to calculate its performance.

*Indicates an outcome associated with a core quiz, all of which had to be passed to earn a grade of "C" or higher.

Appendix B

Guided Practice: Property Data

Based on the guided practice assignment model by Talbert [17].

<u>Overview</u>

We're going to work on how to determine which phase or phases are present in a system. We'll also practice looking up property data in tables.

<u>Learning Objectives</u>

Basic Learning Objectives

You will be responsible for learning and demonstrating proficiency in the following objectives prior to group work activities.

- Sketch *T*-*v*, *p*-*v*, and phase diagrams.
- Locate states on *T*-*v*, *p*-*v*, and phase diagrams.
- Use tables to determine properties of superheated vapors, using linear interpolation when necessary.

Advanced Learning Objectives

The following objectives should be mastered by you during and following the group activities in this module through active work and practice.

- Estimate properties of liquids.
- Evaluate properties of two-phase liquid-vapor mixtures.

Resources

Reading

Read Ch. 3-3.6, 3.9-3.10 in the textbook. Pay attention to the following:

- Figures and bold terms in section 3.2
- Definition of quality (equation 3.1)
- Linear interpolation
- Section 3.6
- Section 3.10

Viewing

Watch the following videos. These have a total running time of 19 minutes, 52 seconds.

- Linear Interpolation (4:01 total. You can stop at 2:00; the remainder refers to software we won't use.) (embedded video: https://youtu.be/4Y0vNuOUbbw [23])
- Advanced Interpolation (5:17 total. You can stop at 4:39.) (embedded video: https://youtu.be/b1DeF2q2ZnU [23])
- Two-Phase Liquid-Vapor Mixture Example (4:34) (embedded instructor-created video)
- *p*-*v*, *T*-*v* Diagrams Example (6:00) (embedded instructor-created video)

Exercises

These exercises can be done during or after your reading and video watching. They are intended to help you make examples of the concepts you are reading and watching. Work these out on scratch paper, and then you will be asked to submit the results at the end.

1. Determine the phase or phases in a system consisting of water at 20°C and 50 bar. Sketch *p*-*v* and *T*-*v* diagrams showing the location of the state.
2. For R-134a at 1.6 bar with a specific enthalpy of 250 kJ/kg, determine the phase or phases present.
3. For R-22 at 25 $lbf/in.^2$ and 42°F, what is the specific internal energy?

Submission Instructions

Click on the "Submit Assignment" button and type or upload your answers to each of the exercises.

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