Engineering Undergraduates' Task Interpretation during Problem-Solving in Thermodynamics

Dr. Oenardi Lawanto, Utah State University

Dr. Oenardi Lawanto is an associate professor in the Department of Engineering Education at Utah State University, USA. He received his B.S.E.E. from Iowa State University, his M.S.E.E. from the University of Dayton, and his Ph.D. from the University of Illinois at Urbana-Champaign. Before coming to Utah State, Dr. Lawanto taught and held several administrative positions at one large private university in Indonesia. He has developed and delivered numerous international workshops on student-centered learning and online learning-related topics during his service. Dr. Lawanto's research interests include cognition, learning, and instruction, and online learning.

Dr. Angela Minichiello P.E., Utah State University

Angela Minichiello is an assistant professor in the Department of Engineering Education at Utah State University (USU) and a registered professional mechanical engineer. Her research examines issues of access, diversity, and inclusivity in engineering education. In particular, she is interested in professional formation, engineering problem-solving, and the intersections of online learning and alternative pathways for adult, nontraditional, and veteran undergraduates in engineering.

Prof. Jacek Uziak, University of Botswana

Jacek Uziak is a Professor in the Department of Mechanical Engineering of the University of Botswana. He received his MSc in Mechanical Engineering from the AGH University of Technology in Krakow, Poland and his PhD in Technical Sciences from the University of Life Sciences in Lublin, Poland. For the past 35 years he has been working at universities mainly in Poland and Botswana; his career includes teaching and research assignments also in Canada, Czech Republic, Norway, UK, Netherlands, France, Germany and USA. He specializes in engineering mechanics and teaches courses in this area. He has particular interest in engineering education.

Mr. Andreas Febrian, Utah State University

He received his bachelor and master degree in computer science (CS) from Universitas Indonesia, one of the top university in Indonesia. He was an active student who involved in various activities, such as research, teaching assistantship, and student organizations in the campus. He developed various CS skills through courses and research activities, especially in computer architecture, robotics, and web development. Through being a teaching assistant and joining student organizations, he developed an interest in psychology and Affective Computing. Currently, pursuing the Doctoral degree in Engineering Education at Utah State University with focuses in self-regulated learning in engineering design.

WIP: Engineering Undergraduates' Task Interpretation during Problem-Solving in Thermodynamics

Abstract

This work in progress aims to better understand engineering students' task interpretation (i.e., accurate understanding of a task) processes while engaged in problem-solving o f introductory engineering thermodynamics course. Task interpretation determines the approach taken toward problem-solving; inaccurate interpretation of problem- solving tasks will consequently result in a failed problem-solving attempt. Task interpretation is theorized to be a complex process that involves identifying explicit, implicit, and social- contextual aspects of identified problems. Two research questions guided the study: (1) What are the gaps, if any, between the instructor's and students' interpretation (explicit and implicit task features) of a problem-solving task?; and (2) How do students' task interpretation (explicit and implicit) change after engaging in self-evaluation of their problem-solving processes? One hundred twelve (112) second year engineering undergraduates voluntarily participated in the study. The preliminary analysis revealed that students faced challenges interpreting tasks related to the assigned thermodynamics problems, even after engaging in self- evaluation of their problem solutions. It was also found that students experienced greater difficulty identifying the implicit task information than the explicit task information that was presented to them in the problem-solving assignments.

Introduction

"A problem well put is half solved." — John Dewey

Problem-solving skills are some of the most critical skills for students to learn [1]–[3]. An accurate and complete understanding of a problem is necessary for learners to select the most appropriate strategies for solving it [4]–[9]. Moreover, in the field of engineering, problems often involve hidden constraints and/or requirements that are not easily identified—especially by novice engineers [10]. Previous studies have reported that students' selection of problem solving strategies are influenced by several factors including their task interpretation, personal conceptualizations and prior learning experiences related to the problem [11]–[13]. Task interpretation is broadly defined as students' judgment about the required cognitive processes to answer a problem [14]. Studies reported that people who can self-regulate appropriately (i.e., engage in coherent planning, enacting, and monitoring activities) based on a correct and complete interpretation tend to be more successful in academia [15], [16], problem-solving [17]–[19], and engineering design [4], [20], [21].

Task Interpretation in Self-Regulated Learning

Task interpretation refers to one's understanding of a problem, including knowledge of the required cognitive process to solve it [14]. Students' interpretation of tasks is considered as an important work habit that is foundational to successful task engagement. Previous studies suggest that a student's task interpretation evolves during a learning or a problem-solving endeavor [22], [23]. Hadwin argues that student's task interpretation can be categorized into three types: explicit, implicit, and socio-contextual task interpretation [24]. Explicit task interpretation refers to "information that is overtly presented in task descriptions and discussions” (p.2) [24], such as task requirements and constraints. Implicit task interpretation refers to “information [that] students might be expected to extrapolate beyond the assignment description” (p.2) [24], such as relevant concepts and cognitive processes. Socio-contextual task interpretation refers to students’ knowledge about the task-related discipline(s) [24], [25]. In this study, we only focus on the implicit and explicit aspect of task interpretation.

This study views task interpretation as an integral part of self-regulation. Self-regulated learning (SRL) is a complex, iterative, and situated goal-directed learning process [5], [8], [26]. SRL is comprised by the student, learning environment, and learner’s engagement with the environment and is affected by student’s emotion and motivation [7], [9], [26]. Student’s engagement starts with task interpretation. Task interpretation is followed by (a) developing a plan based on the task understanding, (b) enacting the plan, (c) monitoring the progress and approach, and (d) making any adjustments as necessary. Adjustments can lead to reinterpreting the task or making new plans and selecting different strategies to solve the problem. This makes the self-regulation process as an iterative activity. A number of studies suggest that self-regulated skills are correlated with high academic standing [15], [16], [27]–[31]. Studies also suggest students’ problem-solving approach, including task interpretation, is influenced by their peers. However, as stated in the previous paragraph, we only focus on students’ self-regulation in this study [22], [23].

Within engineering education, and, particularly within introductory thermodynamics course contexts, it has been reported that students require varied supports while learning basic thermodynamics concepts and principles [32]. Van Meter, for example, designed and implemented an intervention to improve students’ conceptual understanding of and reasoning on introductory thermodynamics problems [33]. From an SRL perspective, the results of these studies suggest that early undergraduates have difficulty developing accurate and complete understandings of thermodynamics problems. The SRL literature documents several evidence-based teaching strategies that are purported to enhance students’ self-regulation skills [34]–[36]. Self-evaluation is one example of such an instructional approach. During self-evaluation, students are commonly provided problem solutions and asked to reflect on their own problem-solving approaches or results. Self-evaluation has been applied in technology [37], [38], engineering [39]–[42], science [13], [43], and mathematics [44], [45].

Research Questions

Two research questions were developed to guide this study:

1. What are the gaps, if any, between the instructor’s and students’ interpretation (explicit and implicit task features) of a problem-solving task?
2. How do student’s task interpretation (explicit and implicit) change after engaging in self-evaluation of their problem-solving processes?

Methods

The purpose of this study is to better understand engineering students’ task interpretation processes while engaged in problem solving tasks in an introductory engineering thermodynamics course. This study also seeks understanding about how student self-evaluation during problem solving activities influences students’ understanding of the problem (or task) they are working on. This study used a mixed-methods research approach wherein qualitative data were generated among volunteer student participants using a questionnaire, quantized by two independent raters, and then analyzed using descriptive and inferential statistical techniques [46]. Due to the researchers' specific interest in studying students engaged in thermodynamics problem solving, purposeful sampling within an engineering thermodynamics course was employed to recruit participants [47]. Participation was voluntary; participants were periodically reminded during the study that they could withdraw at any time. The participants were informed of the purpose of the study by researchers, who were not the course instructor, during class time within the first two weeks of the start of the course. Prior to participation in the study, volunteers were required to sign a consent form as part of the processes approved by the Institutional Review Board (IRB). Overall, one hundred and twelve (112) students in the course (10 female and 102 male) participated in the study; female participation in the study (8.9%) closely represented the female population with the course (9.4%). After the study was complete, all participants received eight extra credit points at the end of the course. Students in the course who elected not to participate in the study were provided an equivalent opportunity to earn the same number of extra credit points.

A Task Analyzer Questionnaire (TAQ) was used to assess participants' explicit and implicit task interpretation during the study. Since this questionnaire is a context-sensitive instrument, three problem-solving assignments were developed for the study. Each problem was designed to address students' learning on a particular thermodynamics course topic including: (1) closed system energy analysis (i.e., the First Law analysis); (2) open system entropy balance (i.e., a Second Law analysis); and (3) ideal cycle analysis which combined use of both First and Second Law concepts. Specifically, the three problems were assigned during the 7th, 13th, 15th weeks of the course, respectively. A unique TAQ was administered for each problem assignment; each TAQ consisted of eight open-ended questions and included items related to both explicit and implicit aspects of task interpretation as described by Hadwin [24]. Examples of an explicit and implicit task interpretation questions were "What were your goals in solving this problem? (In other words, what were you asked to do?)" and "List the major concepts and/or principles discussed in class that you used in solving this problem", respectively.

For each problem assigned, the students were asked to complete the TAQ twice: once before and once after engaging in a self-evaluation activity. The self-evaluation activity was designed after the study described by Kearsley et al. [42] and required students to (a) reflect on their thought processes and answers while comparing their personal problem solution with the instructor's detailed solution and (b) make revisions to their original problem solutions. There was no other specific instructions related to self-evaluation given to the participants other than, when correcting personal solutions, students were required to (a) use a different color pen color to make corrections to their original work (see Figure 1) and (b) electronically scan and then resubmit their revised solutions through the course learning management system.

Two raters, including the course instructor and a senior mechanical engineering faculty member who was also a content expert, assessed students' task interpretation of each of the three problems.. In order to generate quantized measures of the participants' text-based TAQ responses, the instructor provided initial instructor TAQ responses. The content expert then evaluated the instructor TAQ responses and, after discussions between the instructor and the content expert, final instructor TAQ responses were agreed upon. The final instructor TAQ responses were then used by both raters to quantitatively score each participants' TAQ responses. Together, the two raters achieved an inter-rater reliability score of 97 percent agreement.

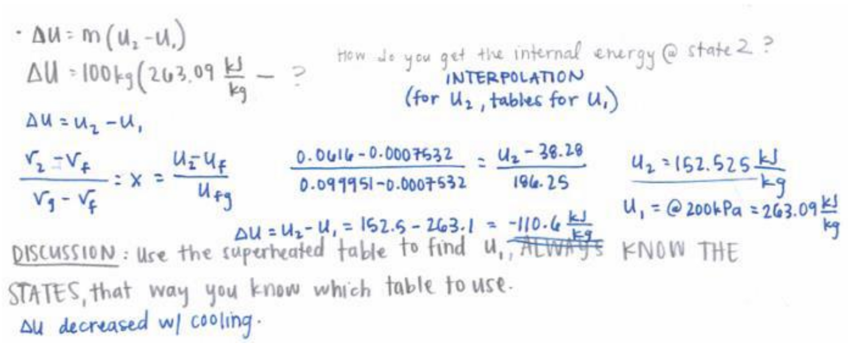

Figure 1. An example of a participant's final corrected solution.

Participants' TAQ scores ranged between from 0 to 2. A TAQ score of 0 was assigned to a blank or incorrect answer; a score of 2 was given to a correct answer (i.e., when students were able to describe at least half of the possible correct responses); and a score of 1 indicated an incomplete answer. To analyze the score, a comparison of the means of students' TAQ responses before and after self-evaluation of the problem solution was conducted. Next, two-tailed paired-sample t-tests were conducted. A cutoff value of .05 for Type 1 error was used to determine whether the results of the TAQ before and after are significant. Inferential statistics will also be conducted to see the statistical significance of the identified differences.

Preliminary Findings and Discussion

Preliminary analysis revealed that the participants' overall (i.e., explicit and implicit together) task interpretation scores before engaging in self-evaluation of the problem solution was 1.098 (i.e., 54.8%) and after engaging in self-evaluation of the problem solution, students' overall task interpretation score was to 1.110 (i.e., 55.5%). This suggests that (1) students only had a partial understanding of the problems presented to them, and (2) even after reviewing the solution of the problem students' ability to interpret (or understand) the problem increased by only 6%. This preliminary finding suggests that student participation in self-evaluation activities, as employed in this study, may not be sufficient to ensure that students acquire accurate and complete understanding of the tasks required to solve fundamental problems in thermodynamics.

From further analysis, it was also revealed that students' overall explicit task interpretation scores before and after engaging in self-evaluation of the problem solution were very similar, 1.364 (i.e., 68.2%) and 1.372 (i.e., 68.6%), respectively. However, students' overall implicit interpretation scores were far below their explicit task interpretation scores, 0.831 (i.e., 41.5%) for before and 0.848 (i.e., 42.4%) after engaging in self-evaluation of the problem. This finding suggests that the students experienced more challenges identifying information beyond the problem description, such as the purpose for the problem assigned and connections to learning concepts.

Table 1 shows that the participants' overall task interpretation scores increased from problems A to B, and from B to C, both before and after engaging in self-evaluation. It is interesting to find that the changes of task interpretation scores before and after the self-evaluation decreases. However, inferential statistics will need to be conducted to determine the significance level of the TI's changes.

Table 1. Students' overall task interpretation scores

Problem	Overall Task Interpretation		
	Before Engaging in Self-Evaluation	**After Engaging in Self-Evaluation**	**Δ**
Problem A	0.996	1.063	0.067
Problem B	1.138	1.123	-0.015
Problem C	1.158	1.142	-0.016

Preliminary Conclusion

In this study, we assessed the accuracy of students' understanding of the presented information in typical introductory thermodynamics course problems and their competency in extrapolating that information. We found that students' reported overall understanding of these problems was incomplete. Further, our finding suggested that students' were only capable of understanding about 68.2% of the explicit information presented in the problem and extrapolating about 41.5% of the implicit relevant information associated to the problem. This finding is worrying because students seemed to incapable of fully understand the typical thermodynamics course problems. This information may inform and help thermodynamics instructors to reflect on their students and design an intervention to address this issue. Additionally, students' self-evaluation of the problem solutions may help improve their task interpretation skills; however, this study showed some improvement only on students' implicit task interpretation skills while solving the least difficult problem. Self-evaluation of the problem solution did not seem to significantly improve students' task interpretation scores when it comes to solving problems that are more difficult.

Future Analysis

During future analyses, inferential statistics (i.e., paired-t-tests) will be used to investigate whether there are statistical differences, or gaps, between the instructor's and participants' interpretation of assigned problem tasks (i.e., overall, explicit, and implicit TI scores). Paired-t-tests will be also conducted to evaluate whether there were changes in the participants' task interpretation scores (i.e., overall, explicit, and implicit TI) after engaging in self-evaluation for any of the three assigned problems.

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