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Developing an Instrument to Measure Motivation, Learning Strategies and Conceptual Change

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Abstract

Recent studies have shown that some students are graduating from engineering programs while still holding onto misconceptions in areas such as statics, electricity and magnetism, and thermodynamics. While considerable research has been devoted to promoting conceptual understanding, few studies have focused on the intentional ways that students can engage in learning that can affect conceptual change. Intentional strategies include motivational factors and the learning strategies students use. In an effort to understand the relationship between intentionality and conceptual change, we are conducting a five-year NSF-funded study that focuses on difficult concepts taught in thermodynamics courses. The overall study is mixed methods using interviews, surveys and real-time experience sampling methods. We are currently in the first phase and this paper focuses on the development of a survey instrument to measure student's motivation, learning strategies and conceptual understanding. We draw on existing instruments and scales to represent a broad range of constructs in a survey instrument that we believe will be useful for engineering education researchers and practitioners alike. Although our pilot testing sample size was small, documenting our process of survey development yields meaningful insights for engineering education researchers and practitioners.

Introduction

One focus of engineering education research is on how students understand concepts and how they address misconceptions. Significant research has focused on the development of methods to assess conceptual knowledge in concept areas such as physics, statics, thermodynamics and others [1-3]. Other researchers have dedicated efforts towards understanding how learners come to understand concepts [4-8]. While many researchers are focusing on conceptual understanding, few are looking at the intentional ways that students engage in learning and how this engagement affects conceptual understanding. To begin bridging this gap, we are undertaking a study to examine motivation, the intentional learning strategies students use and conceptual understanding. Therefore, this paper focuses on the development of a survey instrument to measure the motivational factors that students engage in, the learning strategies they choose and conceptual change in the content area of thermodynamics. Deploying the survey is the first step in a three-phased NSF study that ultimately aims to develop strategies for the teaching and learning of thermodynamics that support student's motivational needs as shown in Figure 1. The larger study has been described in greater detail elsewhere but context for the purpose of the study follow the figure [9].

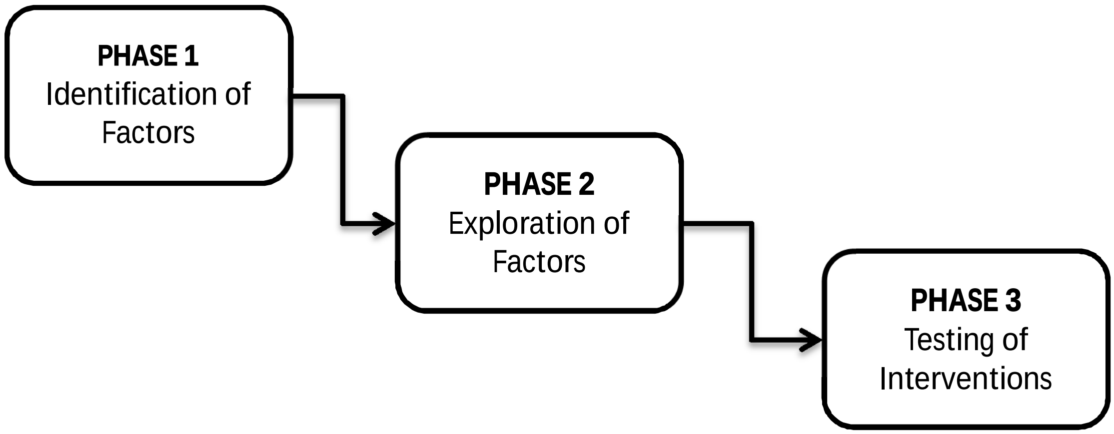

Figure 1: Phases of a Five-Year Study on Motivation and Conceptual Change

Phase 1

Phase 1 of our study focuses on the identification of the motivational factors and learning strategies that students engage in that affect conceptual change in thermodynamics. To gather data for this phase, we used predominantly existing surveys and combined scales and items into a survey that will be deployed nation-wide to students currently taking thermodynamics courses. Using the outcomes from the survey, we will develop interview protocols to probe deeper into the learning process, to help us explain survey results and to begin to identify motivationally appropriate teaching and learning strategies that will work to help students learn thermodynamics. The survey is structured in three parts: Motivation Section, Learning Strategies Section, and Conceptual Understanding Section. After tracing the development of each part of the survey we present pilot results.

Framework

Because we are looking at the intentional ways that students engage in learning difficult engineering concepts, our study is situated at the intersection of motivation and cognitive perspectives, an intersection called “hot cognition” by Pintrich [10]. Both our overall study and the framework have been described in greater detail elsewhere but we provide a brief overview here to help the reader contextualize the survey we are constructing. Linnenbrink and Pintrich proposed a framework, shown as the simplified schematic in Figure 2, to explain how motivation and approaches to learning related to developing conceptual understanding [11]. The fundamental concept underlying the model is that motivation for conceptual change determines how learners approach the task of learning. While not the only model addressing motivation and conceptual change, this model provides a good starting point; the simplistic nature and the fact that it combines constructs from across a variety of theories make it useful in this exploratory research context where little is currently know about relationships among constructs.

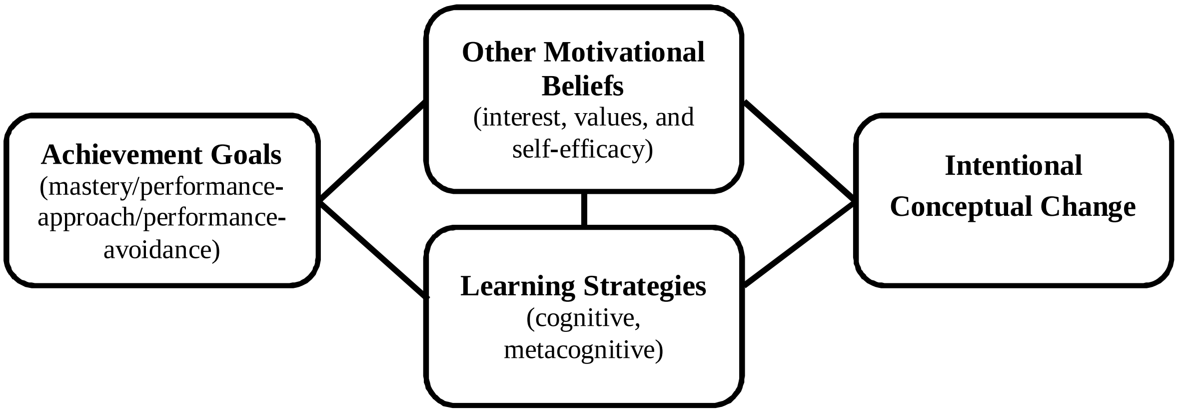

Figure 2: Framework for Intentional Conceptual Change

Research Questions

Consistent with our framework and overall project design, this study is guided by three research questions: 1) what aspects of existing motivation and learning strategies survey items should be included in a survey designed to measure motivation, learning strategies and conceptual understanding in thermodynamics courses? 2) how should the items be worded to focus on thermodynamics courses separate from student's overall engineering course loads? 3) What were the results (reliability scores for surveys and means and correlations across scales) for the pilot administration of the instrument?

Developing the Motivation Section

We started survey development by identifying the relevant motivation constructs to be considered. Considering a broad range of motivation theories, the original list of motivation constructs included extrinsic and intrinsic motivation [12], identification with academics [13], attainment value [14], cost value [14], competence [14], utility value [14], self-efficacy [15], interest [16], expectancy [14], achievement [17], and instrumentality [18]. Knowing such constructs have a rich history in educational psychology research, we searched the literature to locate established survey instruments for each of the motivation constructs under consideration. Table 1 in Appendix A provides a complete list of all survey instruments that we examined and compared for this study.

For each motivation construct, the existing survey instruments were compared side by side. Instruments were selected for inclusion in the Phase 1 survey based on several criteria. First, most surveys were developed using statements as opposed to questions (i.e. Getting a good grade in this class is the most satisfying thing for me right now [19]). Therefore, during selection of scales, we only considered using the scales that were worded as statements so that participants would not be confused when survey items switch between statements and questions. This was true for all constructs except expectancy, where no scale was available that was positively worded as a statement. In this case, the questions available from the Self and Task Perceptions questionnaire (i.e. Compared to other students, how well do you expect to do in math this year? [20, 21]) were reworded into statements. Following this process, the following scales were considered for inclusion in the Phase 1 Survey (shown in Table 1).

Table 1: Initial Instrument Selections for Motivation Section	
Construct	*Survey Instrument*
Extrinsic Motivation	Motivated Strategies of Learning Questionnaire (MSLQ) [19]
Intrinsic Motivation	Motivated Strategies of Learning Questionnaire (MSLQ) [19]
Identification with Academics	Devaluing Scale (Reverse Coded by Jones) [21]
Attainment	Intrinsic Motivation Inventory (IMI) [22, 23]
Competency	Perceived Competence Scale [24]
Utility	Intrinsic Motivation Inventory (IMI) [22, 23]
Self-Efficacy	Motivated Strategies of Learning Questionnaire (MSLQ) [19]
Interest	Intrinsic Motivation Inventory (IMI) [22, 23]
Instrumentality	Perception of Instrumentality - Endogenous, Exogenous [25]
Expectancy	Self and Task Perceptions – Expectancy [20, 21]
Cost	EVT Scale [26]

Second, we worked on shortening the survey. The initial motivation section contained 55 questions addressing 11 constructs. Knowing that the motivation section was only one part of the survey we worried about survey fatigue [27] and reconsidered all questions for possible overlap. After further comparison, we found that there was significant overlap between the competency, expectancy and self-efficacy questions. Self-efficacy has been a construct that has been found to be significant in many engineering contexts [e.g., 28]; therefore the decision was made to eliminate the questions for competency and expectancy. There was also significant overlap between the utility and instrumentality questions and we opted for the instrumentality questions. Across other constructs we eliminated questions that were deemed too similar such as repeating questions that were reverse coded.

The final Motivation section for the Phase 1 Survey contains 25 questions that cover 8 motivation constructs: extrinsic and intrinsic motivation, interest, attainment value, cost value, identification with academics, self-efficacy and instrumentality. All constructs are measured on a 7-point Likert scale ranging from not true at all (1) to very true (7).

Developing the Learning Strategies Section

To develop an appropriate survey to measure learning strategies used in college thermodynamics courses, we started with a literature review to identify existing learning strategies instruments. The following learning strategies inventories were considered for the Phase 1 Survey.

Table 2: Initial Instrument Selection for Learning Strategies Section
Learning and Study Strategies Inventory (LASSI) [29]
Student Perceptions of Classroom Knowledge-building (SPOCK) [30]
Approaches to Teaching Inventory (ATI) [31]
Patterns of Adaptive Learning Scales (PALS) [32]
Self-Regulated Learning Inventory (SRLI) [33]
Motivated Strategies for Learning (MSLQ) [19]

While several of these scales have been used in studies in an engineering context [34, 35], they have not been validated in the specific context of a problem solving course such as thermodynamics where students may not use the types of strategies typically measured such as outlining readings or memorizing terms. We define a problem solving course as any course that focuses on developing skills to solve open-ended problems and need an instrument appropriate for use in such courses. Although popular, the Learning and Study Strategies Inventory (LASSI) scale was eliminated from consideration due to the cost per administration fee that makes it impractical for use in many classrooms. Therefore, we selected the Self-Regulated Learning Inventory (SRLI) as a starting point. The original inventory was modified to fit in the context for a thermodynamics course. For example, the following survey item

> In order to prepare for class, I make enough time for reading and making notes on the assigned material.

was broken into two questions and worded to reflect a thermodynamics context. The items used in the Phase 1 Survey are

> In order to prepare for thermodynamics class, I make enough time for doing the assigned homework problems.

> In order to prepare for thermodynamics class, I make enough time for doing the assigned readings.

We re-evaluated all questions in light of current engineering education literature. For example, Litzinger posed that different cognitive and metacognitive strategies are used by students in problem solving courses than in non-problem solving courses [36]. Therefore, we eliminated several questions in the SRLI that were not relevant in a problem solving course context which also helped keep the total length appropriate to avoid survey fatigue.

Finally, to supplement the SRLI where we thought we had insufficient questions for our context, several questions were added from the Learning Strategies section of the Motivated Strategies of Learning Questionnaire (MSLQ) [19]. The MSLQ was designed specifically for use in college classroom settings.

The final Learning Strategies section for the Phase 1 Survey contains 31 questions covering 11 constructs. The constructs for the learning strategies portion of the Phase 1 Survey were developed using the original categorizations (scales) suggested during the development and validation of the SRLI [33] including Planning, Keeping Records, Environmental Structure, Memorizing, Seeking Info from Peers, Seeking Info from Teachers, Rehearsing, Transforming, Self-Evaluation, Monitoring and Self-Consequences. Not all of the original constructs from the SRLI are included in the Phase 1 survey due to the fact that several questions were not considered relevant in a problem solving course context. All constructs are measured on a 7-point Likert scale ranging from not true at all (1) to very true (7). A list of the pilot questions for the Phase 1 Survey can be found in Appendix B.

Selection of Concept Inventory Questions

To assess participant's conceptual understanding, we drew on the Thermal and Transport Concept Inventory (TTCI). The TTCI is a series of multiple choice questions used to assess conceptual understanding. Each question provides a correct answer and several incorrect answers (called distractors) that fall in line with generally held misconceptions for that concept [1]. The TTCI was developed using rigorous Delphi methodology which is described elsewhere [3].

The TTCI has three sections: thermodynamics, heat transfer and fluid mechanics. We used the Thermodynamics portion of the TTCI because it covers the concepts (specifically focusing on the 1st and 2nd Law) that we found were most consistently covered across mechanical and chemical engineering courses in a sampling of schools. The Thermodynamics portion of the TTCI contains 24 multiple choice questions covering 5 concept areas: entropy and the second law, internal energy versus enthalpy, steady-state versus equilibrium, ideal gas law and conservation of mass. Three questions were selected to include in the survey in an effort to minimize the time required to complete the full survey. The three questions focused specifically in the areas of entropy and the second law, internal energy versus enthalpy and ideal gas law. The future plan was to use the survey instrument as a pre/post-test. By selecting three questions, we created the ability to keep one question constant between the pre and post-test.

Piloting the Survey

Pilot Sampling Procedure

We contacted the instructors of the thermodynamics courses at a large southeastern university and asked them to distribute an invitation to participate in the pilot survey to their students. We also asked the student representatives of the student chapters of ASME and AIChE to distribute an invitation to participate in the survey to their members. An incentive was offered for participation in the pilot survey. All participants were notified that those who completed the survey would be entered into a drawing for a $10 Amazon Gift Card.

Sample Participants

Participants for the pilot survey are comprised of engineering students at a large southeastern university in the US who have been enrolled in at least one semester of thermodynamics. There were 24 partial responses to the pilot survey, with 16 participants completing the full survey including the demographic section at the end of the survey. Because we distributed through listserves and instructors, we do not know how many potential participants received invitations. However, based on enrollments in ME thermodynamics courses, we estimate 250 people were invited to participate in this study. Therefore, the response rate for the pilot survey is estimated to be 6.4%. We acknowledge having a low response rate as a limitation to this study but continued with analysis because we believed the responses could still provide meaningful pilot information. Table 3 shows the demographic information of the participants that completed the full survey. Given our small sample size, we do have surprising ethnic diversity and women are over-represented.

Table 3: Demographic Information for Pilot Study Participants (N=16)

Sex	*n*	*%*
Male	9	56%
Female	7	44%
Race/Ethnicity	*n*	*%*
African American or Black	0	0%
American Indian or Alaska Native	1	6%
Asian	3	19%
Hispanic or Latino/a	2	13%
Native Hawaiian or Other Pacific Islander	0	0%
White	10	63%
Choose not to Disclose	0	0%
# of Courses completed	*n*	*%*
One course in progress	1	6%
Completed one course	9	56%
Completed two courses	6	38%
Year in Degree Program	*n*	*%*
1st year	0	0%
2nd year	3	19%
3rd year	8	50%
4th year	3	19%
5th year	2	13%
Other	0	0%
Major	*n*	*%*
Chemical Engineering	10	63%
Material Science	1	6%
Mechanical Engineering	5	31%

Motivation Section

Table 4 displays descriptive statistics for the motivation constructs used in the Phase 1 survey. Interest and self-efficacy have the lowest means while identification with academics holds the highest mean. Intrinsic motivation, interest, attainment, and self-efficacy have values of Cronbach's Alpha above 0.70 which support the reliability of these constructs [37]. Extrinsic motivation, cost, identification with academics and instrumentality each have a Cronbach's Alpha of less than 0.70 which points to concerns about the reliability of the questions used to measure these constructs [37]. For these constructs, we will revise the questions and re-pilot the survey. Because the questions already came from valid and reliable instruments, and we made few modifications to wording, we focused only on internal consistency reliability in evaluating our version of the combined survey.

Table 4: Pilot Data Motivation Constructs

Construct	*N*	*# of Items in Construct*	*Mean*	*StDev*	*Cronbach's Alpha*
Extrinsic Motivation	24	3	5.43	0.92	0.51
Intrinsic Motivation	24	4	5.34	1.05	0.84
Interest	24	3	4.74	1.54	0.87
Attainment	22	3	5.80	0.97	0.95
Cost	22	2	5.25	1.11	0.34
Identification with Academics	22	2	6.10	0.84	0.60
Self-Efficacy	19	6	4.73	1.26	0.93
Instrumentality	19	4	5.08	1.10	0.62

Learning Strategies Section

Compared to the motivation section, the learning strategies section had more questions that were modified constructions from existing instruments or were new questions entirely. Table 5 displays the descriptive statistics of the learning strategies constructs for the Phase 1 Survey. The constructs of Keeping Records, Seeking Information from Peers, Seeking Information from Teachers, Monitoring and Self-Consequences provide high estimates of internal consistency. There are several learning strategies constructs that provide unacceptably low estimates for internal consistency: Planning, Environmental Structure, Memorizing, Rehearsing, Transforming and Self-Evaluation. We will revise the Planning, Environmental Structure, Memorizing, Rehearsing, Transforming and Self-Evaluation constructs and pilot those questions again.

Table 5: Pilot Data for Learning Strategies Constructs					
Construct	*N*	*# of Items in Constructs*	*Mean*	*StDev*	*Cronbach's Alpha*
Planning	15	2	5.40	1.14	-0.44
Keeping Records	15	3	5.18	1.40	0.92
Environmental Structure	15	2	4.93	1.31	0.12
Memorizing	16	2	3.50	0.97	-0.13
Seeking Info Peers	16	3	3.85	1.70	0.85
Seeking Info Teachers	16	3	4.63	1.43	0.79
Rehearsing	16	5	4.84	1.01	0.60
Transforming	16	2	3.44	1.38	0.40
Self-Evaluation	16	3	4.40	1.19	0.60
Monitoring	16	3	5.17	1.31	0.77
Self-Consequences	16	2	5.50	1.32	0.81

Concept Inventory Section

Table 6 displays information regarding the participant's ability to correctly answer the concept inventory questions in the Phase 1 Survey. Participants had the most success with Concept Inventory Question #2 (CI2) with 82% of participants correctly answering this question. On Concept Inventory Question #3 (CI3), only 19% of participants answered correctly. The average score (CI Total) for all participants in the concept inventory section was 53%.

Table 6: Concept Inventory Questions		
Variable	N	% Correct
CI1	17	59%
CI2	17	82%
CI3	16	19%
CI Total	16	53%

Because the questions do not all perform the same (i.e., question 3 appears to be more difficult than the other two), we would likely choose not to split them up for the pre and post-test administration as originally anticipated.

Correlation between Motivation and Conceptual Understanding

To begin to understand potential connections between motivation and conceptual understanding, a correlation analysis[38] was conducted between the motivation constructs and the concept inventory questions. Correlation analysis is thought to be an appropriate method for analyzing the data at this point in our study due to the low number of survey responses. In future analyses, regression analysis will be the preferred method of analysis.

The correlation matrix for motivation and conceptual understanding is shown in Table 7. While there are interesting correlations between several of the motivation constructs used in this study, our focus is on looking at the correlations between motivation and conceptual understanding. From our pilot study, there are positive correlations between a participant's intrinsic motivation, interest, self-efficacy, instrumentality and their level of conceptual understanding (as measured by CI Total). There is also a negative correlation between extrinsic motivation and conceptual understanding. Interestingly, we also found that different correlation patterns existed among the individual CI questions with CI1 having more negative correlations than the other CI questions.

Table 7: Correlation Matrix for Motivation and Concept Inventory Questions

	EM	IM	INT	ATT	COST	IDENT	SE	INST	CI1	CI2	CI3	CI Total
EM	1											
IM	0.04	1										
INT	-0.16	0.18	1									
ATT	0.19	-0.03	0.13	1								
COST	0.11	-0.11	-0.11	0.51	1							
IDENT	0.41	0.09	0.22	0.80	0.59	1						
SE	0.11	0.65	0.03	0.39	-0.10	0.23	1					
INST	0.07	0.54	0.36	0.02	0.28	0.29	-0.06	1				
CI1	-0.05	0.28	-0.16	-0.05	-0.40	-0.20	0.39	-0.19	1			
CI2	0.03	0.42	0.53	-0.17	0.09	0.11	-0.18	0.63	-0.37	1		
CI3	-0.39	0.15	0.56	0.00	0.11	0.08	0.14	0.04	-0.29	0.23	1	
CI Total	-0.27	0.59	0.58	-0.15	-0.19	-0.04	0.29	0.29	0.38	0.50	0.57	1

EM – Extrinsic Motivation, IM – Intrinsic Motivation, INT – Interest, ATT – Attainment Value, COST – Cost Value, IDENT – Identification with Academics, SE – Self-Efficacy, INST - Instrumentality

Correlation between Learning Strategies and Conceptual Understanding

We also conducted a correlation analysis between the learning strategies constructs and conceptual understanding. This correlation matrix is show in Table 8. There are only a few learning strategies constructs that seem to correlate with the total score for conceptual understanding: Seeking Information from Teachers, Rehearsing and Transforming. The low number of significant correlation could be due to the fact that the learning strategies scales used in the piloting round are not reliable instruments and need to be adjusted further for future use. Like the correlation with motivation, we also noticed that CI1, CI2, CI3 and CI total appear to correlate differently with different factors. Keeping all three CI questions on future implementations should help us explain this phenomenon going forward.

Table 8: Correlation Matrix for Learning Strategies and Conceptual Understanding

	Planning	Keeping Records	Environmental Structure	Memorizing	Seeking Info - Peers	Seeking Info - Teachers	Rehearsing	Transforming	Self-Evaluation	Monitoring	Self-Consequence	CI1	CI2	CI3	CI Total
Planning	1														
Keeping Records	-0.58	1													
Environmental Structure	-0.03	-0.14	1												
Memorizing	0.03	-0.44	0.25	1											
Seeking Info - Peers	-0.06	0.44	0.18	0.09	1										
Seeking Info - Teachers	-0.08	0.57	0.45	-0.20	0.57	1									
Rehearsing	-0.21	0.51	0.29	-0.08	0.29	0.73	1								
Transforming	-0.15	0.33	0.05	-0.06	0.23	0.58	0.32	1							
Self-Evaluation	-0.24	0.52	-0.03	-0.30	0.17	0.48	0.32	0.40	1						
Monitoring	-0.15	0.51	0.25	-0.38	0.25	0.58	0.32	0.30	0.23	1					
Self-Consequence	-0.52	0.73	0.08	-0.50	0.28	0.57	0.32	0.41	0.70	0.53	1				
CI1	0.00	-0.08	0.19	-0.14	-0.20	0.32	0.32	0.50	0.45	-0.20	0.35	1			
CI2	0.03	-0.30	0.04	0.26	-0.14	-0.21	0.32	-0.02	-0.48	0.28	-0.38	-0.37	1		
CI3	0.21	0.14	-0.14	0.09	0.21	0.17	0.32	-0.16	-0.03	0.11	-0.19	-0.29	0.23	1	
CI Total	0.14	-0.18	0.10	0.11	-0.12	0.23	0.32	0.28	0.03	0.08	-0.08	0.38	0.50	0.57	1

Discussion and Conclusions

Consistent with our framework and overall project design, this purpose of this study was to develop and test a survey instrument. Our work was guided by three research questions: 1) what aspects of existing motivation and learning strategies survey items should be included in a survey designed to measure motivation, learning strategies and conceptual understanding in thermodynamics courses? 2) how should the items be worded to focus on thermodynamics courses separate from student's overall engineering course loads? 3) What were the results (reliability scores for surveys and means and correlations across scales) for the pilot administration of the instrument? Outcomes from our pilot study suggest that we have further work to do in developing and testing our instrument. However, this process has hinted at several important implications for engineering education practice and research.

Reconfiguring the Survey Instrument

From the pilot study conducted for the Phase 1 Survey, there are several adjustments that we have identified that need to be made. First, there are several motivation constructs with low reliability results. Specifically, the constructs of extrinsic motivation, cost, identification with academics and instrumentality need to be readjusted. We plan to identify questions that were eliminated from the original constructs and replace those questions in an effort to boost the reliability of these constructs. We suspect that part of the challenge is that we are attempting to measure motivation for a single class and students may have trouble discerning the costs of a thermodynamics course, for example, from the costs of engineering coursework in general.

Second, there is evidence that several of the learning strategies questions need significant work. The constructs of Planning and Environmental Structure have very low estimates of internal consistency. We plan to replace these two constructs with the Time and Study Environment construct developed in the MSLQ [19]. The original Phase 1 Survey questions asked participants where they study for thermodynamics class. The Time and Study Environment construct asks study location questions in terms of study location for school in general. We believe that the general language used by the MSLQ Time and Study Environment construct will be more relevant to participants and will provide a higher level of internal consistency. We also plan to reword and add questions to the Memorizing, Transforming, Rehearsing and Self-Evaluation constructs. In particular, the Self-Evaluation construct may pose an interesting challenge. Some researchers believe that, because metacognition is an unconscious process, it is difficult for participants to answer self-report questions about their metacognitive practices [39, 40].

Finally, we plan to add an open-ended question at the end of the motivation section and the learning strategy to gather information on areas of motivation or specific learning strategies that we may not have considered in this first round of testing. We realize that we may not have covered every relevant learning strategy that students use in thermodynamics. Therefore, the use of an open-ended survey will allow us to gather information on learning strategies that were not covered in existing learning strategies instruments.

Implications for Practice and Research

While it is too early to make definitive statements about how motivation and learning strategies affect conceptual understanding, correlation analyses between motivation, learning strategies and conceptual understanding show promising results that warrant further investigation. Understanding these relationships could have direct classroom implications. For example, a negative correlation between extrinsic motivation and conceptual understanding might suggest that faculty could work towards creating a classroom environment that supports and rewards intrinsic motivation. This is consistent with prior suggestions for college classrooms [41]. While much is known about how to create such classrooms for K-12 [e.g., 42, 43], less research is available with regard to the "how" for college classrooms.

The survey development process that we have described here also has several implications for researchers. First, the fact that our items did not directly translate from existing surveys to our context is an important reminder about the need to check validity and reliability when using and adapting surveys. Second, our low response rate points to the need to consider a different way to attract participants as our work continues. For example, students that find thermodynamics difficult or find that their performance is poor may be less likely to participate in a study on thermodynamics because these students are averse to the thermodynamics context. We plan to engage partner sites directly in an effort to recruit more students in the future. One method that Dillman suggests for improving response rates in through the use of rewards[44]. We have developed an incentive plan for faculty members that will help pass on information about the study in an effort to reach more students.

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Appendix A

Table 1: Scales Considered for Motivation Section							
Intrinsic Motivation	WPI - Challenge, Enjoyment [45]	AMS - To Know, Toward Accomplishment, To experience Stimulation [46]	MSLQ - Intrinsic Goal Orientation [19]	SIMS – Intrinsic [47]	WEIMS – Intrinsic [48]	Scale developed by Hulleman [49]
Extrinsic Motivation	WPI – Outward [45]	AMS - Identified, Introjected, External Regulation, Amotivation [46]	MSLQ - Extrinsic Goal Orientation [19]	SIMS - Identified Regulation, External Regulation, Amotivation [47]	WEIMS - Integrated, Identified, Introjected, External Regulation [48]	
Identification with Academics	Identification with Academics Scale – Osborne [13]	Identification with School Questionnaire [50]	Devaluing Scale (Reverse Coded by Jones) [21]			
Competence	IMI - Percieved Competence [22, 23]	Percieved Competence Scale [24]	Basic Psychological Needs Scale [51, 52]			
Utility Value	IMI - Value/Usefulness [22, 23]	Self and Task Perceptions – Usefulness [20, 21]	Scale developed by Hulleman [49]			
Self-Efficacy	MSLQ - Self-Efficacy [19]	LAESE - Engineering Self-efficacy [53, 54]	General Percieved Self-Efficacy Scale [55]			
Interest	IMI - Interest/Enjoyment [22, 23]	Self and Task Perceptions - Intrinsic Interest [20, 21]	Scale developed by Hulleman [49]			
Attainment Value	IMI - Effort/Importance [22, 23]	Self and Task Perceptions - Attainment Value/Importance [20, 21]				
Cost Value	Qing Li JEE [56]	EVT Scale [26]				
Expectancy	Self and Task Perceptions – Expectancy [20, 21]					
Achievement	Scale developed by Hulleman - Mastery, Performance [49]					
Instrumentality	Perception of Instrumentality - Endogenous, Exogenous [25]					

Appendix B

Table: Motivation Section of Phase 1 Survey (Pilot)		
Construct	*Survey*	*Question*
Extrinsic	MSLQ	The most satisfying thing to me would be to get a good grade in thermodynamics class.
		If I can, I want to get better grades in my thermodynamics class than most of the other students.
		I want to do well in my thermodynamics class because it is important to show my ability to my family, friends, employer or others.
Intrinsic	MSLQ	I prefer course material that really challenges me so I can learn new things.
		I prefer course material that arouses my curiosity, even if it is difficult to learn.
		The most satisfying thing for me in this thermodynamics class is trying to understand the content as thoroughly as possible.
		When I have the opportunity, I choose course assignments that I can learn from even if they don't guarantee a good grade.
Interest	IMI	I enjoy thermodynamics class very much.
		I think that thermodynamics class is boring.
		I would describe thermodynamics class as very interesting.
Attainment Value	IMI	I put a lot of effort into my thermodynamics class.
		I try very hard in my thermodynamics class.
		It is important to me to do well in my thermodynamics class.
Cost	EVT Scales	The amount of effort it will take to do well in my thermodynamics class this term is worthwhile to me.
		The amount of time I spend on thermodynamics keeps me from doing other things I would like to do.
Identification with Academics		It is important to me to get good grades in thermodynamics.
		It is important to me to learn the course material in thermodynamics.
Self-Efficacy	MSLQ	I believe that I will receive an excellent grade in thermodynamics class.
		I'm confident I can understand the BASIC concepts taught in thermodynamics class.
		I'm certain I can understand the MOST DIFFICULT material presented in thermodynamics class.
		I'm confident I can do an excellent job on the assignments and tests in thermodynamics class.
		I expect to do well in thermodynamics class.
		I am capable of learning the material presented in thermodynamics class.
Instrumentality	Endogenous Instrumentality	The information presented in thermodynamics class is important for my future ACADEMIC success.
		The information presented in thermodynamics class is important for my future CAREER success.
		The grade I receive in thermodynamics class is important for my future ACADEMIC success.
		The grade I receive in thermodynamics class is important for my future CAREER success.

Table: Learning Strategies Section of Phase 1 Survey (pilot)		
Construct	*Survey*	*Questions*
Planning	SRLI	I make enough time for doing the assigned homework problems.
		I make enough time for doing the assigned readings.
Keeping Records	SRLI	I keep my assignments, class notes, and old tests in one place so that I can review them when necessary.
		I take notes in thermodynamics class.
		I use my notes when working on homework problems and studying for tests.
Environmental Structure	MSLQ	I usually study for thermodynamics class in a place where I can concentrate on my course work.
		I have a regular place set aside for studying for thermodynamics class.
Self-Consequences	SRLI	If my grade for this class is sliding, I will focus more on studying for thermodynamics class.
		If I have problems with an assignment or test in thermodynamics class, I study harder instead of ignoring my problems.
Self-Evaluation	MSLQ	I often find that I think I understand how to do a problem when I see the instructor do it in class. Then when I attempt to do a practice problem, I realize I do not understand how to do the problem.
		When studying, I try to determine which concepts I don’t understand well.
		If I get confused taking notes in class, I make sure to sort it out later.
Monitoring	SRLI	I know how well I am doing in thermodynamics by keeping track of my grades.
		I am aware of how well I understand my thermodynamics assignments.
		I am aware of how well I understand what is presented in thermodynamics lecture.
Memorizing	SRLI	When I study, I try to understand and apply the information instead of just memorizing enough to “get by.”
		When studying, I memorize the steps needed to solve a problem.
Seeking info - Teachers	SRLI, MSLQ	I find out what my instructor thinks is important and make sure that I study that material.
		I ask the instructor to clarify concepts that I don’t understand well in class.
		When I need help with an assignment or understanding the material presented in class, I ask the professor outside of class (like during office hours or through email).
Seeking Info - Peers	MSLQ, SRLI	Even if I have trouble learning the material in thermodynamics class, I try to do the work on my own, without help from anyone.
		When I can’t understand the material, I ask another student in this class for help.
		I study with another person so that I can learn the material in by talking and listening.
Rehearsing	SRLI	When studying, I ask myself lots of questions and make sure that I can answer them.
		I apply what I am learning in thermodynamics class to something I already know or have experienced.
		I practice solving problems to prepare for tests.
		I do the assigned homework.
		I apply what I am learning in thermodynamics class to my “everyday” world outside of school.
Transforming	SRLI	When studying, I put the material into a more simple form, such as an outline, a concept map or a drawing or sketch.
		I summarize and rewrite my class notes.