AC 2012-4736: WHAT IS IMPORTANT IN PHYSICS LEARNING?: UNDERSTANDING LEARNING PERSPECTIVES AND PROVIDING LEARNING ASSISTANCE FOR ENGINEERING STUDENTS

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What Is Important in Physics Learning?-Understanding Learning Perspectives and Providing Learning Assistance for Engineering Students

Abstract

Calculus-based introductory physics courses are known for presenting learning challenges to engineering students. Learning outcomes in these courses affect subsequent student performance in courses that demand a high level of conceptual understanding of physics. In this study we analyze student survey results to explore the impact of factors such as learning goals, study habits and skills, and learning readiness on student outcomes. Survey participants responded to questions from the Maryland Physics Expectations Survey (MPEX), and a mixture of quantitative and qualitative research methods was applied for data collection. Conclusions draw on data analyses using an alternative taxonomy model in the cognitive domain. This study's findings reinforce our view that metacognition (knowledge of cognition) and knowledge construction play an important role in learning. These findings also deepen our understanding of why some engineering students struggle in physics classes and shed light on how to assist students in these courses.

I. Introduction

Calculus-based introductory level physics courses undoubtedly present major learning challenges to many students entering engineering. Most physics and engineering instructors rely on traditional physics teaching, and assume the course content helps students develop problem-solving skills. These instructors also believe that both the content and skills learned in introductory physics are essential to students' success in college, and ultimately in their engineering professions. However, many students lack their instructors' confidence and interest in traditional introductory level physics courses. Our institutional research showed that students who failed to pass these courses often left engineering or withdrew from the college completely.[1] The research also showed that even those who passed these courses were not pleased with their experiences in physics learning. When graduating from college, engineering students frequently state that their physics courses were less satisfactory than those they took for calculus, chemistry, and many other subjects.[2] To address students’ concerns, the College of Engineering and the Physics Department at the University of Wisconsin-Madison have taken several steps to improve teaching and learning. The Physics Department has made changes in areas such as lecture delivery, homework assignments, and exam format. The Engineering College has responded by offering academic support services to assist students’ learning. Since spring 2001, the college has offered a well-structured academic support program, the Supplementary Instruction Program (SI) to support intro-level physics as well as several other courses. The SI program is part of the engineering college's strategic plan to improve and reform engineering education.

Because students' stated reasons for dissatisfaction lack focus, the nature and causes of students’ concerns are not clear. Despite many changes in physics teaching, engineering students continue to express their disappointment regarding physics instruction. Clearly, there is a need to identify causes that lead to students’ dissatisfaction. Our previous work in this area showed that students’ perceptions of the learning environment significantly impacted learning. Students who participated in SI sessions indicated that academic support programs like SI played a key role in fostering effective learning of course material and in promoting a spirit of joyful learning.[1]

Researchers in physics education have found that students' attitudes toward learning significantly impact what students actually learn.[3-7] Several instruments, including the Maryland Physics Expectations Survey (MPEX),[4] Views About Science Survey (VASS),[5] the Epistemological Beliefs Assessment (EBAPS),[6] and the Colorado Learning Attitudes about Science Survey (CLASS)[7] were designed to assess students' attitudes toward learning. Results from extensive survey studies that employ these instruments have been documented and categorized.[8] Causes giving rise to various students' viewpoints have also been examined.[9-12] Our current study focuses on gaining insights into students' perspectives on learning. We explore causes that lead to students' learning beliefs and habits, and examine the impact these beliefs and habits have on learning. This paper describes students' perspectives and identifies factors that significantly affect physics learning. The results help us understand how and why students perceive learning in ways that sometimes diverge from those of physics educators. We believe students' perspectives on learning goals, expectations, and skills have lasting effects on learning, not only in intro-level physics courses, but also in subsequent courses that demand a higher level of conceptual understanding. We are able to identify factors that may potentially hinder students' learning. Our findings are consistent with recent research in the field of physics education, and our concerns are shared by many physics and engineering educators and education researchers. [4, 9-12]

II. Methodology

To understand students' viewpoints concerning physics learning and instruction we constructed a survey using 24 questions from the MPEX[4] (the questions used in our survey are listed in Tables II and III below). From 2002 to 2003, more than 200 students in the Supplementary Instruction Program (SI) participated in the survey. Of these, we had complete surveys for 132 respondents. To facilitate understanding of our survey results, we begin with background information about SI and survey participants. The UW-Madison College of Engineering's Supplementary Instruction Program (SI) has a strong focus on developing problem-solving skills within the course content and shares some common practices established for SI at various institutions for different disciplines.[1] SI programs are designed to target the "at risk" courses. Currently, the UW-Madison College of Engineering's SI is listed as a formal course in the timetable, InterEGR150-SI Problem-Solving Workshop, for zero credits and is managed by the college's Undergraduate Learning Center. It supports two calculus-based intro-level physics courses as well as a course in statics and two in dynamics. Each semester, about 160 students enroll in SI, and 60 or more sign up in three or four sessions that support calculus-based intro-level physics. The program is open to all students who enroll in courses for which SI sessions are offered. It is structured as small study groups offering a peer-instructional and cooperative problem-solving environment, a structure that models many features of genuine engineering practice.

A few characteristics of the 132 survey participants should be mentioned. First, all are SI students and thus voluntarily signed-up for SI's zero-credits and to spend two extra hours working on physics each week. Therefore participants are considered "motivated" or "highly motivated" students. Secondly, the average course grade for the survey participants was a "B", a letter grade higher than the class average of "BC". Among survey participants, 86 scored a course grade of “B” or above. The remaining 46 participants scored “BC” or lower. Thirdly, among the 132 participants, 68 students were asked to indicate their readiness for college physics courses; of these 37 indicated they were “ready to take college physics” while the remaining 31 indicated they were “somewhat ready”. The average course grade for these two groups differs: the “ready” group (n_R=37) had a “B” average, and the “somewhat ready” group (n_{SR}=31) had a “BC” average. Finally, most survey participants completed their college education at the University of Wisconsin-Madison, and 70% of these earned an engineering degree.

Survey questions were categorized under six specific groups as shown in Table (I).[4] Table (I) lists the question labels. Corresponding labeled questions used in this study are listed in Tables (II) and (III). Students indicated their level of agreement to various statements regarding aspects and experiences of learning utilizing a scale of 1 through 3, where “1” indicated “not much”, “2” indicated “some”, and “3” indicated “very much”. “Not applicable” was also a choice.

Table (I): MPEX survey questions[4]

Question group	Desirable responses	Undesirable responses	Question label
Independence	Learns independently and takes responsibility for constructing own understanding	Takes what is given by authorities (teacher, text) without evaluation	I1, I3, I4, I-M5
Coherence	Believes physics needs to be considered as a connected, consistent framework	Believes physics can be treated as separated facts or “pieces”	CH7, CH9,
Concepts	Stresses understanding of the underlying ideas and concepts	Focuses on memorizing and using formulas	CP2, CP8, CP11, CP12, CP13, CP14
Reality link	Believes ideas learned in physics are relevant and useful in a wide variety of real contexts	Believes ideas learned in physics are unrelated to experiences outside the class-room	R6, R10, R15, R16
Math Link	Considers math as a convenient way of representing physical phenomena	Views the physics and the math independently with no relationship between them	I-M5, M18
Effort	Makes the effort to use information available and tries to make sense of it	Does not attempt to use available information effectively	E17, E19, E20, E21, E22, E23, E24

In this study, a “desirable answer” is defined as “agreeing with viewpoints of experts”.[4] Similarly, an “undesirable answer” is defined as disparate viewpoints from those of experts. Data collection was through the method of frequency counting. A revised taxonomy model was applied to analyze data.[13-15]

III. Survey results - What do students think?

Figures 1 and 2 display survey results for all participants.[16] The figures show students' responses according to expert expectations of “desirable” and “undesirable” answers, and Tables (II) and (III) show the actual questions. Figure 1 displays the questions in which many students gave a “desirable” answer, while Figure 2 shows the questions in which many students gave an “undesirable” answer. We find that the majority responded with the “desirable” response in 13 of the 24 questions and with the “undesirable” response in 11 of the 24 questions. The survey questions are displayed at the horizontal axis in both figures, respectively. In both figures, dark bars show the percentage of “desirable answer” and light ones for “undesirable answer”. The percentage of students who chose to respond with “some” is shown with cross patterns and is labeled “neutral”. About half of the survey participants did not indicate strong agreement/disagreement with some survey questions and their responses are termed as “neutral”. Because students were not asked to explain their choices in this survey, we only use responses with indications of either “very much” or “not much” when we define the majority in Figures 1 and 2, respectively. The same definition of “majority” is applied to both Figures 3 and 4.

Figure 1 and Table (II) display the 13 questions that produced a relatively higher percentage of “desirable answers”. As illustrated in Figure 1, most survey questions/statements that received "desirable" responses generally mirror students’ learning experiences and thus these results are quite understandable. For example, students’ responses to statements under the category of “Effort”, (e.g., E20, E21, E22, E23, E24) typically reflect their strong determination to learn well. Three questions in the category of “Independence” also revealed students’ positive attitude toward learning. Almost all participants were well aware of the responsibilities involved in learning (e.g., I1, I4, I-M5). The majority responded adequately to statements that clearly describe the correct methods in physics learning (e.g., CH9, CP11). Students also realized that physics is related to, and helps them solve, real-world problems (e.g., R10, R15, R16).

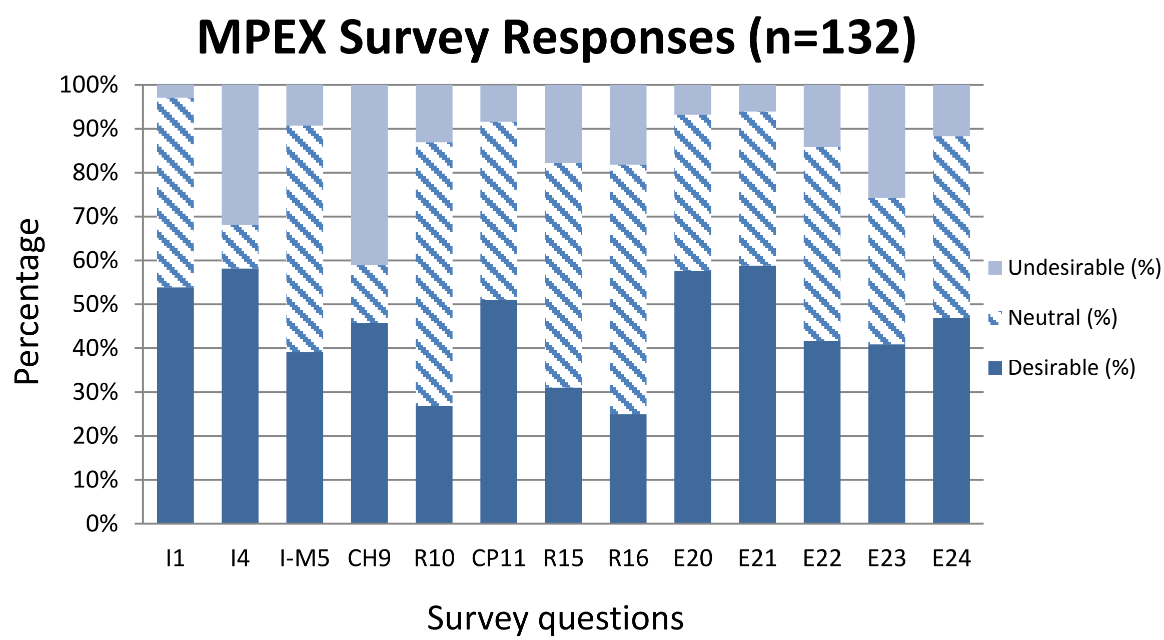


Figure 1. Survey questions (listed in Table (II)) with a higher percentages of "desirable answer".

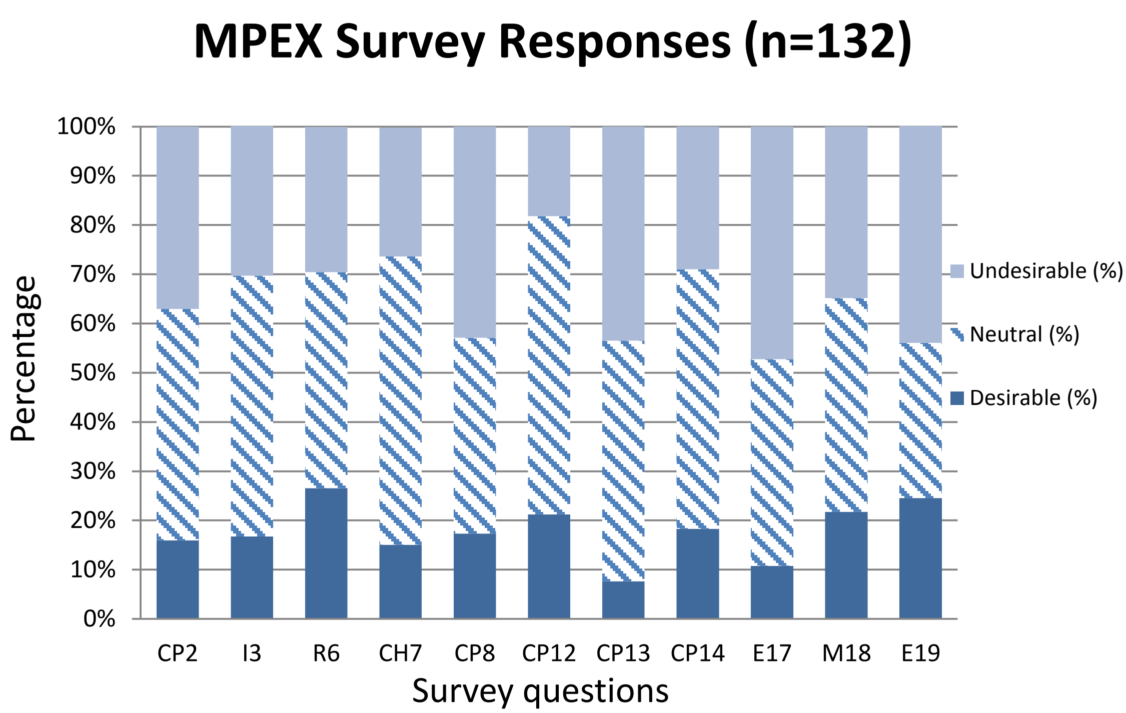


Figure 2. Survey questions (listed in Table (III)) with a higher percentage of "undesirable answer".

Table (II): Questions corresponding to Figure 1 [4]

Question Label	Statement
I1	Learning physics requires that I substantially rethink, and reorganize the information that I am given in class and/or in the textbook.
I4	Only a few specially qualified people are capable of really understanding physics.
I-M5	In this course, I do not expect to understand equations in an intuitive sense; they just have to be taken as givens.
CH9	A significant problem in this course is being able to memorize all the information I need to know.
R10	The main skill I get out of this course is to learn how to reason logically about the physical world.
CP11	To be able to use an equation in a problem (particularly in a problem that I haven't seen before), I need to know more than what each term in the equation represents.
R15	Learning physics made me change some of my ideas about how the physics world works.
R16	Physics is related to the real world and it sometimes help to think about the connections, but it is rarely essential for what I have to do in this world.
E20	I read the text in detail and work through many of the examples given there.
E21	I use the mistakes I make on homework and on exam problems as clues to what I need to do to understand the material better.
E22	The results of an exam don't give me any useful guidance to improve my understanding of the course material. All the learning associated with an exam is in the studying I do before it takes place.
E23	A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough.
E24	It is possible to pass this course (get "C" or better) without understanding physics very well.

While we are pleased to learn that SI students have defined their learning goals and mastered basic study skills, we are also troubled by some of their responses. Table (III) displays the questions that produced a relatively higher percentage of “undesirable answers”. See Figure 2. Specifically, we are surprised that students seemed to respond to certain groups of questions inconsistently.[3,8] For example, students understood that in order to apply an equation, they would need to know more than what each term in the equation represented (CP11). Yet they tended to believe that problem-solving in physics means “matching” (CP12). To understand this apparent disconnect, we asked if this could be the outcome of aggregating data and if in fact there were difference between “high achievers” and others or between students who indicated they were “ready” or “somewhat ready”. Thus we divided students along these two dimensions: the course grade and readiness.

Table (III): Questions corresponding to Figure 2[4]

Question Label	Statement
CP2	All I need to do to understand most of the basic ides in this course is just to read the text, work most of the problems, and/or pay close attention in class.
I3	My grade in this course is determined primarily by how familiar I am with the material. Insight or creativity has little to do with it.
R6	To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.
CH7	Knowledge in physics consists of many pieces of information each of which applies primarily to a specific situation.
CP8	The best way for me to learn physics is by solving many problems rather than carefully analyzing a few in details.
CP12	Problem solving in physics basically means matching problems with facts or equations and then substituting values to get a number.
CP13	The most crucial thing in solving a physics problem is finding the right equation to use.
CP14	The main skill I get out of this course is learning how to solve physics problems.
E17	I spend a lot of time figuring out and understanding at least some of the derivations of proofs given either in class or in the text.
M18	All I learn from a derivation or proof of a formula is that the formula obtained is valid and that is OK to use it in problem.
E19	I go over my class notes carefully to prepare for tests in this course.

Figures 3 (a) and (b) display the questions in which students gave a “desirable” answer for “high achievers” and other students. Here we consider participants who earned a grade “B” or better in the course as “high achievers”. Figure 3(a) is for the “high achievers” (n_h=88). Figure 3(b) is for the other participants who earned a “BC” or lower grade in the course (n_o=46). In Figures 3 (a) and (b) survey questions that produced “desirable” responses from the majority of the two selected groups are compared.[16] In both figures, the dark bar shows the percentage of students who agreed with experts and the light bar for the percentage of students who did not. The patterned bar represents the percentage of “neutral” responses. We notice that students who had lower course grades selected five more “desirable” responses as compared to the group of “high achievers”. (i.e., I3, R6, CP12, CP14, E19 indicated by arrows in Figure 3(b)).

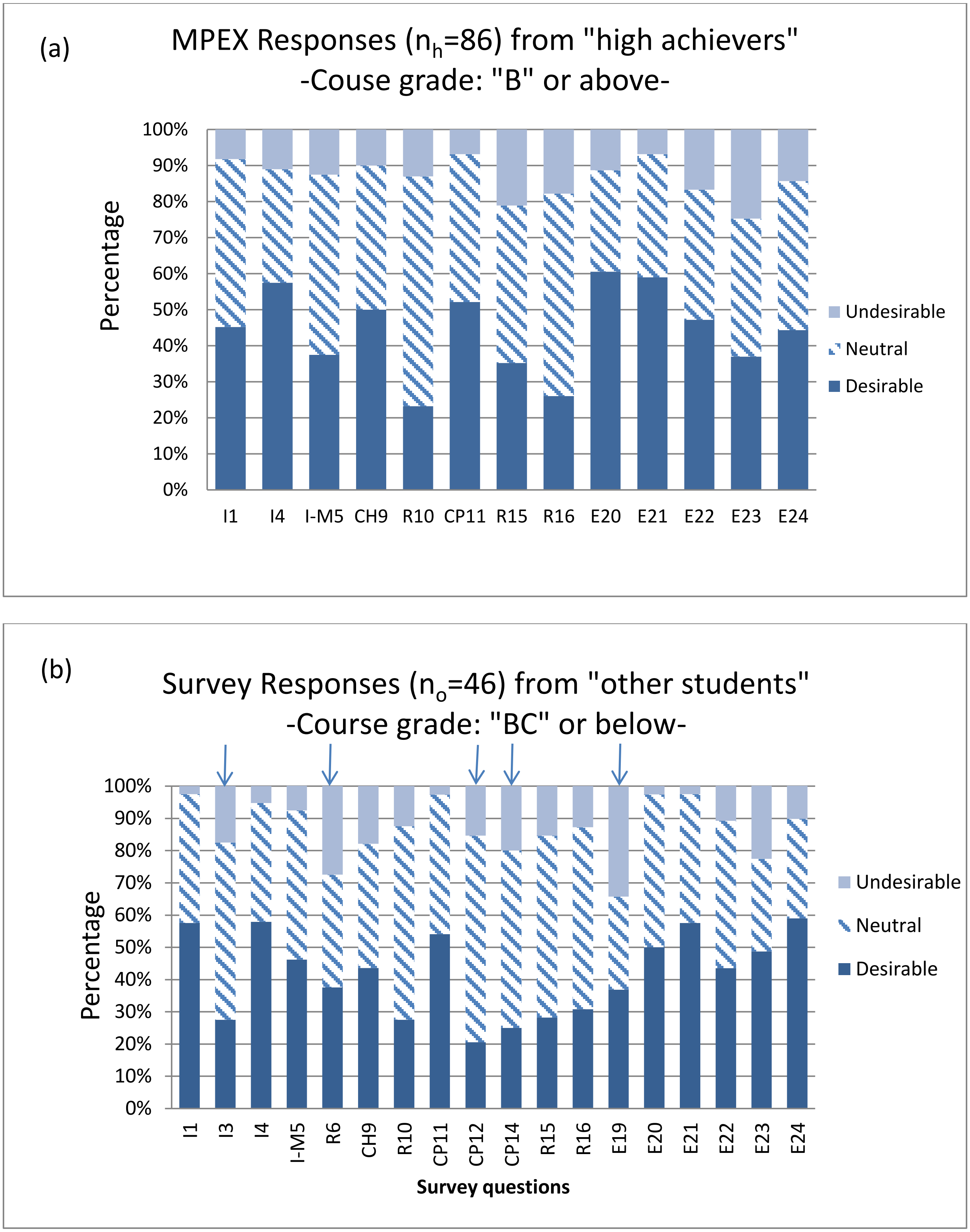
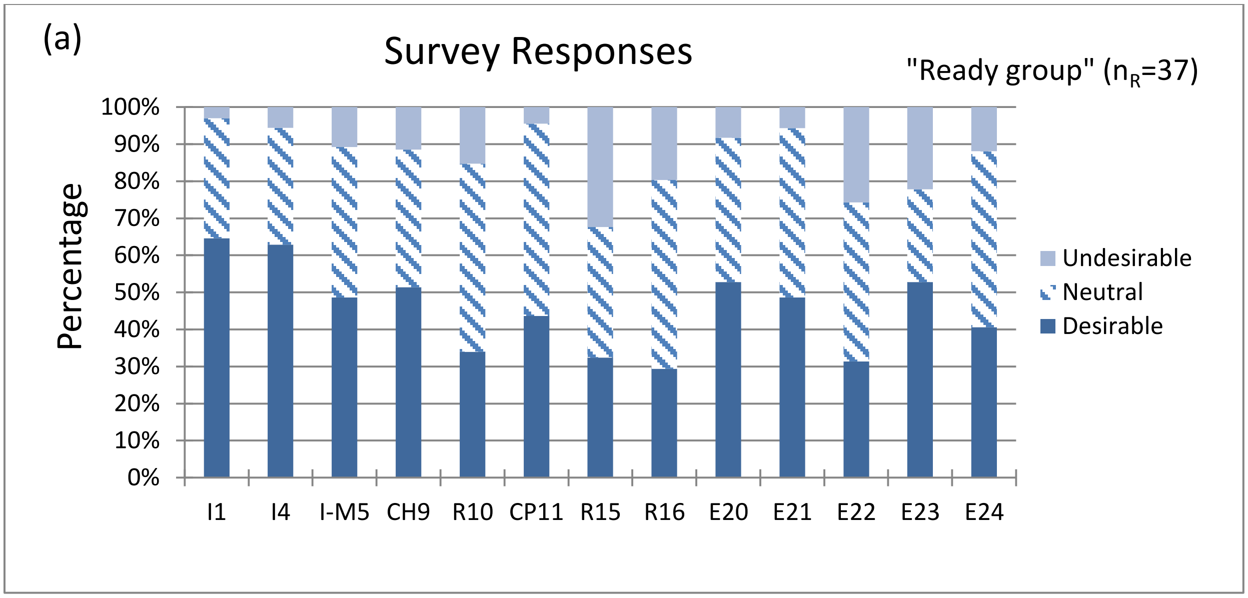


Figure 3. Survey responses: (a) from “high achievers”; (b) from “other students”.



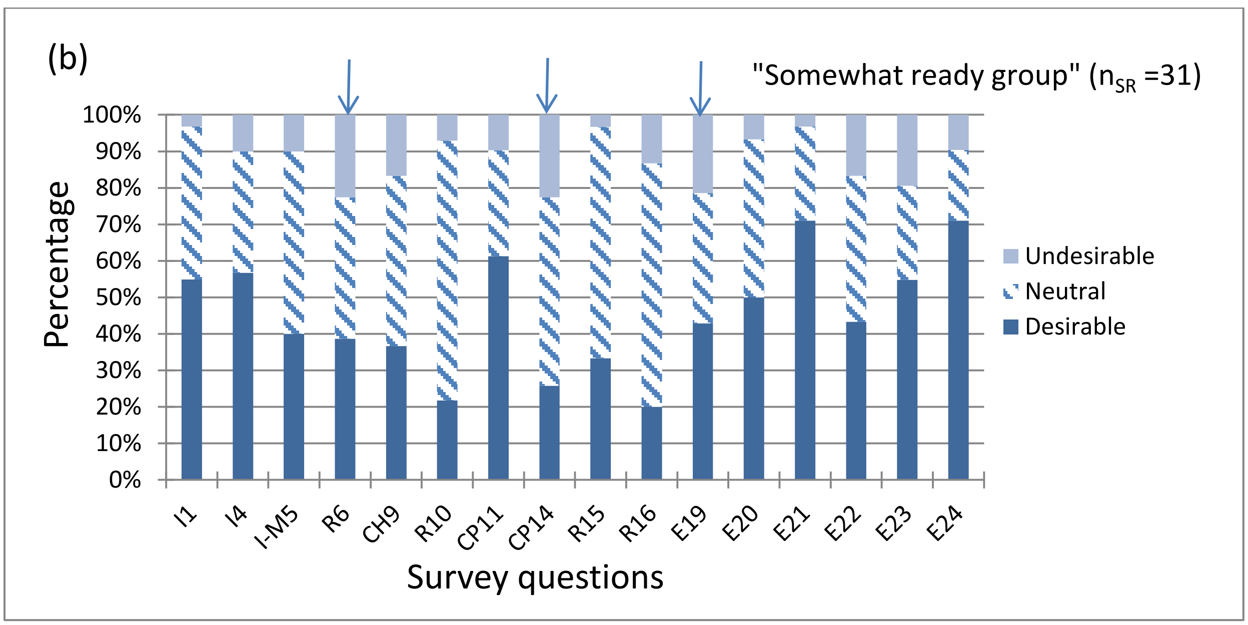


Figure 4. Survey responses: (a) from "ready group", and (b) from "somewhat ready group".

Figures 4 (a) and (b) display the questions in which students gave a "desirable" answer and compare the responses for participants who indicated they were ready or somewhat ready. Figure 4(a) is for students who indicated they were "ready" to take college physics (n_R=37). Figure 4(b) is for students who indicated they were "somewhat ready" to take college physics (n_{SR}=31). We used the self-assessed "readiness" as a reference. These two figures with questions that produced "desirable answers" from the majority of the selected groups, "ready" vs. "somewhat ready", display different responses.[16] Dark bars represent "desirable" responses in both figures. We see that the “somewhat ready” group selected more “desirable” responses than their “ready” peers. (i.e., R6, CP14, E19 indicated by arrows in Figure 4(b)).

IV. The meaning of the results – Applying an alternative taxonomy model.

Clearly, Figures 3 and 4 do not show the correlations between students’ course grades and their perspectives of learning in survey questions that one would hope to see. Specifically, when we include course grades as one of the parameters, we obtain seemingly contradictory results. Students who were portrayed as “high achievers” based on their course grade did not score high in the MPEX survey. Students who claimed “readiness” did not score high in the survey either. These results suggest that course exams and MPEX measure different and unassociated aspects of learning outcomes, at least on the level we examined. Where does the inconsistency come from? Are there any flaws or limitations in our analyses?

Before we seek answers to these questions, we want to be certain that these results are representative. Every semester, intro-level physics courses have enrollment ranges of 200 (for physics (I)) and 350 (for physics (II)). More than 80% of the enrolled students choose engineering as a major, and about 10%-25% of these students enroll in SI sessions. Since spring of 2001, about 1300 students have participated in SI for physics. Because SI is designed to support “at risk” courses, not “at risk” students, SI students represent high and low academic achieving groups equally. One can only argue that the SI group draws students who are highly motivated, and as expected, they earned high marks in questions under “Effort”.

To identify causes leading to students’ viewpoints, particularly those under “Concepts” and “Coherence”, we must further quantify these results. In a traditional content-centered physics lecture, we rely heavily on exams to assess students’ learning progress, and grades to measure learning outcomes. The focus on test scores drives students to seek ways of gaining good grades above all else. Programs such as SI that are designed to promote a true and joyful learning experience often struggle to overcome the widely-held perception that high achievers are defined by good course grades alone. For many instructors test grades are such a handy tool that they are inclined to use it whenever possible. When we first looked at how students’ readiness affects their course performance, we applied a hypothetical universal model, shown in Figure 5, to explain our data. This model is based on typical practices in traditional physics courses for content delivery and assessment. In this figure, three typical groups of knowledge are used. Traditional physics courses recognize these three classes of knowledge i.e., factual, conceptual, and procedural as fundamental knowledge. Both teaching and learning are assumed to start from basic factual knowledge, such as terminologies and statements of various laws, and to progress to procedural knowledge, which is problem-solving within the course content. Exam grades assess the level of content knowledge and mastery. The degree of “readiness” can be used as a variable to determine the slope of the line. For students who are well prepared to take college physics courses, their learning progress can be described by a steep line that leads to a better course grade in the end. By simply using a linear function, we can explain why students achieve higher exam grades if they are “ready”. One truth is revealed in this model, however. Students who are “ready” are more likely to survive in traditional physics lecture courses than students who are "not ready", as the steeper curve indicates. We are not sure if this holds in the long term, however.

It is not surprising that the model shown in Figure 5 does not forecast students' ability to apply what they supposedly learned in intro-level courses to subsequent courses. The model is limited in several ways. It does not explain why some students who earn an impressive score in intro-level physics courses struggle in subsequent classes that demand a high level of conceptual understanding. It also fails to explain why “high achievers” defined only by course grades did not score better than lower achievers in surveys that assess their perspectives on learning. The disconnect between student grades and student perspectives on learning suggests that (a) a course grade cannot be the sole measurement of learning progress, and (b) a content-only assessment reveals nothing about levels of learning. As a result, we feel it is necessary to construct tools that will help us assess students’ learning challenges and progress more accurately, particularly in the early stages of engineering education. Recent findings in education research indicate an important fact that has long been overlooked in traditional physics teaching and learning: learning includes both cognitive positions and methodical perspectives, and learning is intensely individualized.[15] These research results help us understand that we need to move away from our traditional ways of thinking, which focus only on content and content instruction. We should use analytical methods in the cognitive domain to understand how students think about physics learning and what their learning challenges are. We resort to the revised Bloom’s taxonomy by Anderson and Kratwohlm,[13] and reference the taxonomy of significant learning by Fink.[14] Both models have a strong emphasis on cognitive thinking and learning.

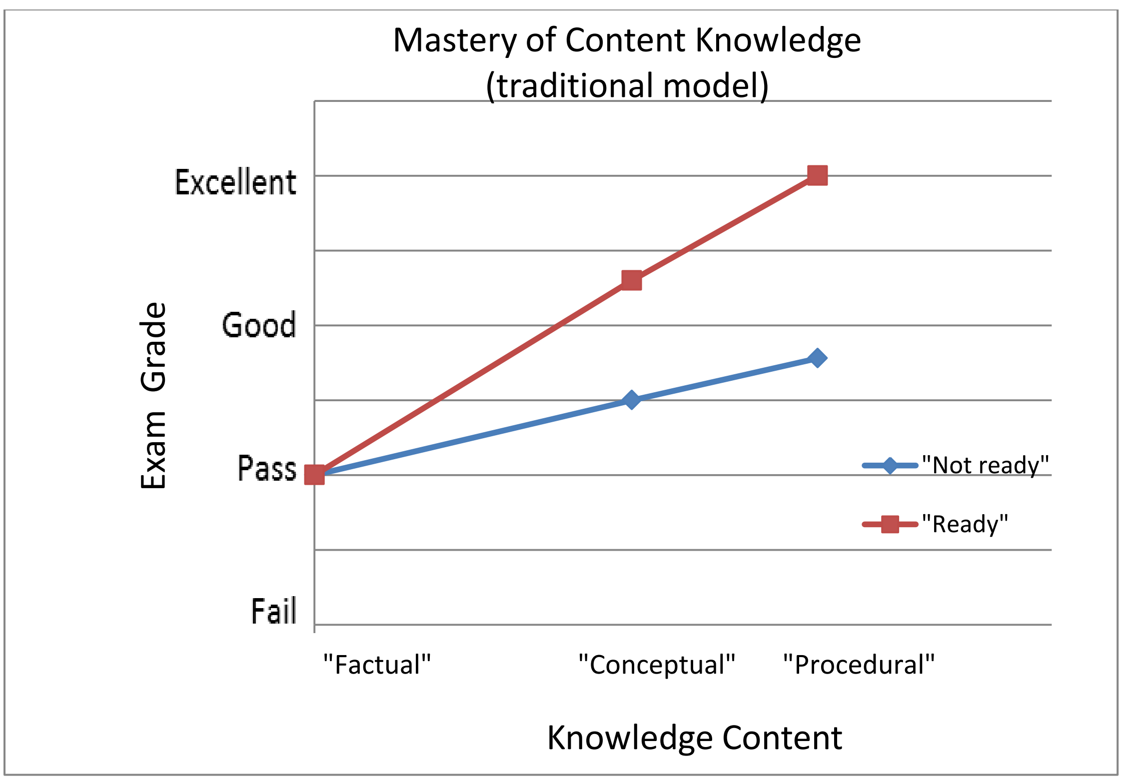


Figure 5-A traditional model assessing content-only learning outcomes.

Students' responses are mapped to the modified taxonomy model that highlights cognitive levels, as shown in Table (IV). Six groups of survey questions defined by the MPEX are re-categorized following the model by Anderson and Kratwohl. [13] Individual survey questions are marked by four classes of knowledge: factual, conceptual, procedural, and metacognitive (knowledge of cognition in general as well as ones' own cognition), from concrete to abstract. Students' responses to these questions are analyzed by cognitive thinking levels displayed from low (remembering) to high (integrating). Whether or not students agree with "expert" opinions, we believe their responses show their learning preferences as well as their perceived or perhaps experienced thinking levels that pertain to physics learning. Each answer is marked by the proper cognitive position. For example, if students expect to learn only concrete but not abstract knowledge in physics, and consider that topics in physics are isolated, they naturally believe that lower thinking skills of remembering and understanding are sufficient. Their response to such questions (e.g., CH7) will unsurprisingly appear in the cell of the intersection between "factual knowledge" and "remembering" level. In Table (IV), questions that produced a "desirable" answer from the majority (Fig. 1) are shown in bold font. Ones that produced "undesirable" answers (Fig. 2) are in italic fonts.

The quantified results in the cognitive domain give us some insight into students' perspectives. One immediately notices a trend displayed in Table (IV): almost all "undesirable" answers appear at lower cognitive levels of "remembering" and "understanding" while the majority of "desirable" answers are at higher levels. This leads to the conclusion that the major difference in attitudes toward learning between students and experts is due to their cognitive disposition. This conclusion raises many questions. Why do students stop short of higher-order thinking levels? Does their cognition disposition hinder learning? Do students learn some unintended things from class? Where does the disconnect between teaching and learning come from?

A few ideas come to mind. Our study shows students' misconception in the area of their learning habits regardless of their course grades and self-identified "readiness" (i.e., I3, CP8, E17, M18). The result provides support for the findings of other physics education researchers who have observed that both high and low achieving students misrepresent their study habits equally on average.[17] Students are willing to spend more time focusing on quantitative activities involving equations and practice problems, and less time focusing on qualitative activities involving concepts and real-life examples. Unfortunately, some students with a higher course grade and self-claimed readiness seemed to have more faith in such distorted learning behaviors; perhaps because they have experienced some degrees of "success" in the past.

Another finding of our study is closely related to one propounded in recent research: i.e., students of all ages have difficulties learning how science knowledge is constructed and in most cases regress in sophistication as measured.[18] Our survey results suggest a possible cause to the misconception of knowledge construction. Students' "undesirable" answers illustrated that most students generally believed that acquiring knowledge through solving problem processes only involved matching problems and facts, and problems and equations. They failed to understand that every learning task requires the advancement of cognitive thinking skills so that the knowledge learned in intro or lower level courses can be transferred and applied to more sophisticated courses and situations. The misconception is replicated in "undesirable responses" to questions of CP2, CP12 and CP14.

Table (IV): Survey results represented by an alternative taxonomy model[13-15]

Knowledge \ Cognitive	Remembering	Understanding	Applying	Analyzing	Constructing	Integrating
Factual (basic elements in a course/discipline)	*CP2, I3, CH7*	*CP2 CP12, M18,* **CH9**	**CH9**	**I-M5, I1, CH9**	**I1,CH9**	**I1, CH9, R10, R15, R16**
Conceptual (interrelationship between basic element within a larger structure that enable them to function together)	*CP2, M18*	*CP14*	**CH9, R16**	**CH9,CP11, I-M5, R15, R10,I1**	**R15, R10, R16**	**R10, CP11**
Procedural (methods of inquiry, and criteria for using skills, algorithms, techniques, and method)	CP2, *CP12*	*CP13, CP14*	*CP8, CP14*	**CH9, R10, CP11, R16**	**CH9, R10**	**CH9**
Metacognitive (knowledge of cognition in general as well as one's own cognition)	*CP2, I3, R6, CH7, CP12*, *CP13,* **I4**	*R6, CH7, CP8, CP14, E17*, *E19*, **E20, I4**	**CP11,R16, I4**	**I4, CP11**	**I1, I4, E23**	**I4, R10, R15,E23**

Students' "undesirable answers" in areas of "Concepts" and "Coherence" in MPEX are suggestive of their limited exposure to metacognitive knowledge defined by the taxonomy model (i.e., knowledge of cognition). See questions CP2, CH7, CP8, CP12, CP13, CP14. Students have certain ideas about knowledge of one's own cognition, for example their readiness for college physics class, but lack the skills to identify their learning strengths, or to construct their own learning strategies, or even the ability to realize when their learning is not going well. Unfortunately, our physics classes and other learning activities have not provided adequate opportunities to allow students to develop and improve their knowledge.

We are also concerned that often our physics courses teach students things about learning that are not intended or desirable. For example, many students believed that solving physics problems involves only finding the right equation, in essence a "matching" game (e.g., CP12, CP13), because learning behaviors like this are sometimes rewarded by higher exam grades (I3). On one hand, we teach students to understand each equation in an intuitive way, which was confirmed by students' responses in the survey. On the other hand, content in our classes is delivered and assessed at the levels of "matching the problem with an equation, and getting a numerical answer". [1] These inconsistencies lead to a disconnect between teaching and learning. We speculate that the fact that many students selected "neutral" answers in this study could be due to such a misconception. Nonetheless, there are students who are not satisfied with the focus of our classes and have told us why. In an end-of semester survey conducted by SI, one student who scored an "A" in the class told us explicitly he was disappointed by the way physics was taught. He wrote, "*I often find the quantity of numerical-based material to be too much---I think our time might be better spent working at a more intuitive, fundamental level. (This is not to say I am not good at math, I am good with my math, but I feel learning physics requires more intuition.)"* We know he is not alone because other students expressed similar concerns.

V. Next steps - How do we assist students to learn?

This study's findings can help us foster physics learning in several ways. It has been suggested that "the common denominator to the new pedagogy is getting students to practice thinking like experts in the subject."[19] To do so, we need to address issues that lead to misconceptions in learning.

We believe it is extremely important that physics instructors provide students with a coherent picture of learning. Students need to understand that physics topics are coherent, and physics phenomena should not be viewed as isolated facts and pieces. Only when students recognize these facts will they be convinced of the need to take consistent approaches to comprehending the subject matter and its underlying laws. Their new awareness will motivate them to advance their thinking levels beyond "memorizing" and "understanding."

The most important goal of any revised physics instructional curriculum should be helping students learn how to learn. Instructional materials to help students develop substantially more sophisticated beliefs about knowledge and learning should be promoted and expanded. Students' new beliefs about knowledge and learning will help them refine approaches to learning new and advanced materials. Learning how to learn requires improving metacognitive knowledge as well. [21] SI students have shown determination and have taken responsibility in their own learning, yet they still lack deep understanding or knowledge of cognition. Some students might be aware of their own cognition, but generally are not equipped with beliefs and skills to overcome learning obstacles. Our study has shown that most students believed that they needed to use memorization when encountering learning challenges particularly in physics. See items shown at the cells of the row of "Metacognitive knowledge" in Table (IV).

Finally, we believe all physics educators should reconsider their teaching approaches. This study reveals that several perceptions in physics education have hindered students' learning. Some of the students' perceptions indicate inconsistencies between content delivery and course assessment, and others suggest a misalignment between teaching and learning. To improve engineering education, including physics education for engineering students, institutions must make culture changes. In his article in the November 2011 issue of Physics Today, David Kramer reported that the Association of American University is pushing to institute new methodologies for STEM education [19]. It's exciting to know that efforts seeking a systematic adoptation to new teaching methods are currently underway.

VI. Summary and conclusions - What should SI do?

Using analytical tools in the cognitive domain, we gained insights into students' perspectives in learning physics. We found some possible answers to why engineering students were less than satisfied with their physics instruction based on our understanding of how students think of learning and what they have experienced in learning. We understand that SI should focus on helping students advance their cognitive thinking levels while continuing to provide a student-centered learning environment. Students have told us that SI has been very effective in helping them identify and learn important concepts and difficult content, and that SI is also very effective in helping them understand how to break down problems to reach a solution.[1] Students appreciated the discussions in SI, which enabled their "real learning", but "not memorizing"[1] . SI challenges students to reflect on their own learning approaches and effectiveness after each midterm exam. All these activities help students learn course content and develop their cognitive levels at the same time. The current study suggests ways in which SI could improve: (a) play an active role in helping to teach students how to learn, particularly those who are not ready for college physics; (b) provide more activities that allow students to think and practice like experts, such as sessions that allow students to reflect on their learning verbally and in writing ; (c) help foster an effective communication channel for instructors and students to allow a better alignment of teaching and learning goals.

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