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What makes physics difficult?

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Abstract: According to many students, introductory physics is difficult. We are investigating what students believe makes physics difficult and what can be done to overcome these difficulties. Our investigation includes an initial free-response survey given to approximately 1400 students in an introductory physics course and a second survey, which was given to approximately 400 students in another semester, distilled from the responses to the first survey. Also faculty members and teaching assistants (TAs) for physics courses are asked to complete the second survey. Our findings show that the perceptions of the students and faculty members are different in terms of difficulties which students have in a physics course. The perceptions of students and TAs are mostly the same. Both students and faculty members agree that student-related factors, such as not studying more have the most influence on students' success in physics.

Key words: Conceptual Understanding, Learning, Physics, Physics Education, Teaching Physics.

INTRODUCTION

Students' views about a course influence their understanding and learning of that course. Many students think and say, "Physics is difficult." Angell et al.(2004) probed the views of high school students and physics teachers about physics. They found that students find physics difficult because they have to contend with different representations such as experiments, formulas and calculations, graphs, and conceptual explanations at the same time. Moreover, they have to make transformations among them. For example, students need to be able to transfer from graphical representations to mathematical representations. Redish (1994) explains why students describe physics as difficult:

> *Physics as a discipline requires learners to employ a variety of methods of understanding and to translate from one to the other--words, tables of numbers, graphs, equations, diagrams, maps. Physics requires the ability to use algebra and geometry and to go from the specific to the general and back. This makes learning physics particularly difficult for many students (p.801).*

The views of faculty members, teaching assistants, and students about learning and understanding physics are in general different (Redish, 1994). Redish describes how students learn physics using an analogy named "the dead leaves model":

> *…it is as if physics were a collection of equations on fallen leaves. One might hold s=1/2g*t^2, another F = m*a, and a third F = -k*x. The only thing one needs to do when solving a problem is to flip through one's collection of leaves until one finds the appropriate equation (p.799).*

Faculty members and TAs should know and understand students' views about physics courses because both are teachers of students. Moreover, they should be able to see how their views are different from students' views. Thus, they can begin to understand why students have difficulties in physics. Otherwise, as Carter and Brickhouse (1989) note, "students, faculty, and teaching assistants will live in different worlds and it will be difficult to communicate because they speak different languages".

Student difficulties stem from physics concepts, the way in which a physics course is taught, and physics problems which are sometimes very vague. However these may not be seen by faculty or TAs as creating difficulties for students. Redish (1994) confirms that; "…we don't understand most of our students and they don't understand us…" (p.802). Redish (1994) gives an example from his experience about how a student and a teacher were in a different world:

> *…I will never forget one day a few years ago when a student in my algebra-based introductory physics class came in to ask about some motion problems. I said "All right, let's get down to absolute basics. Let's draw a graph." The student's face fell, and I realized suddenly that a graph was not going to help him at all. I also realized that it was going to be hard for me to think without a graph and to understand what was going through the student's mind. I never minded doing without derivatives—motion after all is the study of experimental calculus and you have to explain the concept (maybe without using the word) even in a non-calculus based class; but I have found it difficult to empathize with students who come to physics and can't read a graph or reason proportionately…(p.802).*

Having students' views about their difficulties with physics can provide valuable information to the course instructors preparing the course curriculum, choosing the course textbooks, and employing the curriculum in a way that lessens students' difficulties of understanding and learning of physics. Carter and Brickhouse (1998) say, "Faculty views of difficulties influence choice of curriculum, implementation of

Table 1. Student-Controlled Factors

	% of Students N=293	% of TAs N=21	% of Faculty N=4
Lack of motivation and interest	59	71	75
Not studying more	56	67	100*
Not reading the textbook	55	71	75
Not completing CHIP assignment	55	52	0*
Not doing practice many problems	49	57	50
Working only assigned problems	44	24	0*
Not doing homework	41	67*	100*
Lack of previous experience	35	29	25
Lack of physics background	35	33	25
Lack of higher level mathematics	12	27	50*

*Items where students and faculty, or students and TAs seem to disagree according to Independent-Samples t-test at α=0.5 level. Only four faculty members responded to the survey and this might not be enough to discuss the differences between faculty members and students.

curriculum, and the nature of evaluation in physics courses. Therefore, perceptions of difficulty are central to the classroom." Thus we have conducted a study, modeled after Carter and Brickhouse's study of "what makes chemistry difficult, and what could be done to help students overcome these difficulties.", and surveyed the students in a large introductory physics course for science and engineering majors at Purdue University in order to obtain students' views about their difficulties in physics courses.

METHODOLOGY

Research Context

The introductory physics course for science and engineering majors is offered in the fall, spring, and summer semesters. The number of students varies each semester. The course includes two 50-minute lectures, one two-hour recitation in which students work on conceptual and numerical problems, and one two-hour lab every other week. Other elements of the course are Computerized Homework in Physics (CHIP), concept pretests on the web, hand-written homework, reading quizzes on the web, and discussion quizzes in the recitations sessions. TAs are available in a help center during weekdays and weekends. Old exams and lecture notes can be obtained from the course website.

Data Collection

The Initial Survey

We administered a one-page free-response survey to approximately 1400 students in recitation sessions near the end of the fall semester. The students were asked to write five responses to each of the two questions: (1) What makes physics difficult? and (2) What can be done to overcome these difficulties?

After examining all students' responses, we separated the most common replies into three categories: (1) factors that students could control (Table 1), (2) factors that were course-related (Table 2), and (3) factors inherent to the nature of physics (Table 3).

The Second Survey

The second survey listed the 10 most popular items in each of the three categories noted above. We asked about 400 students in spring semester as well as 12 physics faculty members with experience teaching the course, and 31 TAs of the course to choose the five most important items in each of the three categories. In addition we asked which of the categories has or should have the most influence on success in a physics course. Of the 400 students surveyed, 293 replied. Four of the 12 faulty members replied and 20 of 31 teaching assistants replied. Responses of each group are listed in Tables 1.

RESULTS

Discrepant Views

There were several areas which faculty members and students, and TAs and students agree. Also, there are differences in some areas. We discuss these areas for each table separately.

We can categorize the factors in Table 1 into three groups. The first group is the lack of motivation and interest. Faculty members, TAs, and students all agree that the lack of motivation and interest is an important issue for not being successful in physics.

The second group of factors relates to not working hard enough. This group includes not studying more, not reading the textbook, not completing CHIP assignment, not doing many practice problems, working only on assigned problems, and not doing homework. All faculty members and TAs agree that their students do not work hard enough. It is interesting that the students also believed that not working hard enough was an important factor for them.

The last group of factors is background knowledge. This group is composed of lack of previous experience, lack of physics background, and lack of higher level mathematics. Interestingly, faculty members, TAs, and students believe that lack of background knowledge is not the most important obstacle to success physics except that faculty members think that students' mathematics background should be better.

Table 2. Course-Controlled Factors

	% of Students N=293	% of TAs N=21	% of Faculty N=4
Too much work	68	48	50
Hard CHIP homework	66	24*	25
Lack of consistency between the lab/tutorial/lecture and homework	57	43	25
Textbooks, lectures, CHIP homework questions are too complicated	53	33	50
Tutorial sections are not useful	50	43	25
Not enough examples, real life applications, and problem solving especially conceptual questions in class	38	76*	75
Being so picky on grading	36	19	0*
Hard questions on the exams and were not related to what solved in the class	31	43	50
Poor professors	12	62*	50*
Poor TAs	10	57*	50*

*Items where students and faculty, or students and TAs seem to disagree according to Independent-Samples t-test at α=0.5 level. Only four faculty members responded to the survey and this might not be enough to discuss the differences between faculty members and students.

It appears that faculty members, TAs, and students have almost the same beliefs about the issues that cause difficulties in learning physics.

We can categorize the factors in Table 2 into three groups. The first group of factors relates to too much work. This group includes too much work; hard CHIP homework, and textbooks, lectures, CHIP homework questions are too complicated. Students believe that they have to do too much work to be successful in physics, on the other hand, beliefs of faculties and TAs are not strong as much as students' beliefs.

The second group of factors is that structure of class is not useful. This group includes lack of consistency between the lab/tutorial/lecture and homework, tutorial sections are not useful, not enough examples, real life applications, and problem solving especially conceptual questions in class, being so picky in grading, and hard questions on the exams and were not related to what solved in the class. Faculty members, TAs, and students disagree about the usefulness of the structure of class. Faculty and TAs are more positive about the consistency of lab/tutorial/lecture and homework and about the utility of the tutorial sections than are students. Faculty members and TAs believe that there are not enough examples, real life applications, and solving conceptual questions in class, but students see this as less important.

The last group of factors relates to inadequate quality of instructors. This group includes poor professors and poor TAs. Lastly and interestingly, students believe that instructors, including TAs, are good in teaching. Faculty members and TAs do not agree with students because they think they themselves are not good. The faculty members gave themselves a much lower evaluation as instructors than students gave them. This suggests that the faculty members realize that they should be more prepared and do much more in the classrooms. The reason why students think faculty members are adequate may be that students think instructors should have had enough knowledge and ability to teach since they became professors. To TAs, professors are inadequate for teaching as well. Interviews with TAs would be very helpful to find out why TAs think professors are poor.

The issue of the quality of TAs brought out very different results because students do not think that TAs are inadequate even though both faculty members and TAs themselves think they are inadequate. There might be a few reasons for that. Students probably see TAs as supportive and think they are easy to approach and ask questions. Also, in general, TAs are more available than professors. Moreover, TAs are still students; they can understand their students more than professors because professors may already have forgotten how it is like being a student. Also, TAs might be more flexible in terms of grading their exams, homework, quizzes, and lab reports. Faculty members think that TAs are not adequate and do not have enough knowledge of physics. The more interesting thing is that TAs themselves think that they are inadequate as well. This might be due to the lack of physics content knowledge or practice in teaching physics.

We can categorize factors in Table 3 into five groups. The first group is that physics is cumulative. Faculty members, TAs, and students all agree that physics is cumulative. They believe if one concept is missed, it is hard to grasp the next one.

The second group of factors is physics is a very difficult subject and physics is very abstract. Faculty members, TAs, and students all agree that physics is difficult although only the students rank the abstract nature of physics as a problem.

Table 3. Factors Related to the Nature of Physics

	% of Students N=293	% of TAs N=21	% of Faculty N=4
Physics is cumulative. If you miss one concept, it is hard to grasp the next one	77	86	75
Physics is very difficult subject	57	43	75
There is too much material to learn	43	43	0*
Physics is very abstract	41	24	50
Physics requires good mathematics	33	95*	100*
Physics has too much theory	32	43	0*
Physics has too many formulas to be learned	29	29	0*
Physics has too many laws and rules	28	19	0*
Physics is not interesting enough	23	29	75*
Physics cannot be learned without mathematics background	23	57*	100*

*Items where students and faculty, or students and TAs seem to disagree according to Independent-Samples t-test at α=0.5 level. Only four faculty members responded to the survey and this might not be enough to discuss the differences between faculty members and students.

The third group of factors relates to that physics has too many things to learn. This group includes there is too much material to learn, physics has too much theory, physics has too many formulas to be learned, and physics has too many laws and rules. Students and TAs agree that there are too many concepts and too many formulas to learn in physics, and physics has too much theory such as theory of Newton's laws of motion, the general theory of relativity, and the special theory of relativity and many laws such as Newton's first, second, and third laws of motion, and rules for summing or subtracting vectors (force or velocity vectors). On the other hand, faculty members do not agree. Faculty members may have a much better understanding of how many apparently different laws follow from a more general principle, thus they do not regard all the theory, equations, and laws as separate bits of information. This is consistent with the study of Johns and Mooney (1981):

> *… many students are unable to place the concepts in perspective. The result of this difficulty is that the students' knowledge and understanding of physics is frequently fragmented and compartmentalized and they never perceive a unity of the subject (p.356).*

The fourth group of factors is that physics is not interesting. Students and TAs do not indicate that physics is uninteresting enough to make it difficult. Faculty members believe that students find that physics is not interesting and that makes it difficult for students.

The final group of factors relates to a requirement for a good mathematics background. This group includes that physics requires good mathematics and physics cannot be learned without mathematics background. Faculty members and TAs agree that

Table 4. What Influences Success in Physics?

31. From your experience, do you believe the items in Table 1 [Student-Controlled Factors]* or the items in Table 2 [Course-Controlled Factors] most influence your success (your students' success)**in physics?

	% of Students N=293	% of TAs N=21	% of Faculty N=4
(a) Student-Controlled Factors	61	86	75
(b) Course-Controlled Factors	37	14	25

32. In theory, which of the first two tables [Student-Controlled Factors and Course-Controlled Factors] *should* have the most influence your success (your students' success) in physics?

	% of Students N=293	% of TAs N=21	% of Faculty N=4
(a) Student-Controlled Factors	70	76	75
(b) Course-Controlled Factors	29	24	25

33. Is Table 3 [Factors Related to Nature of Physics] more important or less important than the first two tables [Students-Controlled Factors and Course-Controlled Factors]?

	% of Students N=293	% of TAs N=21	% of Faculty N=4
(a) More important	28	9	25
(b) Less important	69	91	75

*The terms in [ ] are not in the survey but we added for the readers' convenience.

**The statement in parentheses ( ) was used in the faculty and TA version of surveys.

physics requires good mathematics and cannot be learned without mathematics background; whereas students think that not having good mathematics background does not make physics difficult.

Most students indicate that it is their fault if they are not successful in physics. In Table 4, 61 percent of students say that student-controlled factors influenced their success more than course-controlled factors in physics. In item 31 and 32, students, the faculty members, and TAs agree about that based on their experiences and theory. In item 33, they all agree that student-controlled factors are more important than course-controlled factors and factors related to the nature of physics. As a result, faculty members, TAs, and students seem to believe that being successful in physics is achievable for students.

DISCUSSION

From the results, we can conclude that students and TAs have almost the same perceptions about the factors which make physics difficult. It may be because TAs still remember what it is like to be new to the subject. Students and faculty members think differently in terms of difficulties which students have in physics. It seems students and faculty live in different worlds. When faculty members understand what students think about physics courses or about physics itself, and how students approach physics, faculty members can prepare or use a curriculum that assist students to learn physics concepts, and to learn and improve physics problem solving. In addition, the faculty members should learn how to reach their students and how to make physics concepts be understood by their students even if they are really sophisticated in their field. Students do not think the faculty members are inadequate.

Even though we cannot generalize our findings to all physics courses because every physics course might be different, we believe the findings about differences between how the faculty members and students think about physics and difficulties in physics can be useful to faculty of physics courses in other universities. We recommend that faculty members try a similar survey for their classes because it would give them an opportunity to see that course in the way their students perceive it.

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REFERENCES

Angell, C., Guttersrud, Ø., Henriksen, E. K. & Isnes, A. (2004). Physics: Frightful, but fun, Pupils' and teachers' views of physics and physics teaching [Electronic version]. Science Education, 88, 683-706.

Carter, S. C. & Brickhouse, N. W. (1989). What makes chemistry difficult? Alternate Perceptions. Journal of Chemical Education, 66, 223-225.

Jones, H. G. & Mooney, R. J. (1981). An approach to conceptual difficulties in physics [Electronic version]. Physics Education, 16, 356-359.

Redish, E. F. (1994). The implications of cognitive studies for teaching physics. American Journal of Physics, 62, 796-803.

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