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**University Physics: Deep Learning, Practice Problems, and Course Success**

**Introduction**

What are the best study strategies for success in university physics courses, and why might this be the case? Research on student preference has shown that students like to focus on problem solving algorithms and memorization techniques. In both “Physics Students Learn by Rote” (1999) by Andrew Elby and “Differences in Student’s Perceptions of Learning Physics” (1996) by Michael Prosser, Paul Walker, and Rosemary Millar, such approaches are considered low-level processing techniques, classified more specifically as “surface approaches”. In Elby’s study, he found that physics students spent more time on “problem solving algorithms…[believing] that exams reward this behavior” (Elby 55). This similar notion is echoed in the latter research paper, which found that 75% of physics students pointed towards reviewing notes, formulas, and exercises while only 21% aimed for a “deeper understanding” through a discussion of principles (Prosser, Walker, and Millar 43). This research concluded that a majority of students use surface techniques and put less importance on understanding or real-world connections (47). Another study called “Achievement Goals, Interest, Study Strategies, and Academic Achievement” (2011) by Thomas Anthony Costello found that the highest performing biology and psychology students who used deep processing strategies also reportedly
used more surface level tactics than the lower performing students (38). Although these results are not in the context of physics courses, it still raises an intriguing question which may be applicable: how are surface level approaches aiding student’s deep understanding of the material? In the context of the two studies done on physics students, one may conclude that surface level approaches are superior for higher grades, since a deeper understanding is not of great importance. However, both articles make the unsupported assumption that the techniques mentioned are purely surface approaches that do not increase a fuller and deeper understanding of the material. Do students who prefer “surface” approaches really gain no conceptual understanding by working through practice problems? When the articles so rigidly define certain activities as either surface or deep level, there is little accounting for the idea that a surface level technique would increase deep understanding. This is important because one might reasonably assume that there is a relationship between conceptual understanding and success in courses, but this is overshadowed by the raw statistics which focus on study methods instead of inquiring about a student’s level of understanding with the material. Therefore, it is important to delve deeper into not just what methods the students use, but how they are processing the material. More specifically, as both articles gave evidence for student preference with practice problems, I will explore these in greater detail. I suspect that study strategies which enhance deep understanding should positively impact course grades, which can include practice problems if approached in such a way that avoids pure memorization techniques.
Research Methodology

It is first important to clarify the primary goals of my research and to clarify what I hope the data can tell me. In essence, I hope to answer these three main questions:

1) How is a conceptual understanding of physics concepts related to success in physics courses?
2) How are practice problems related to surface processing and deep processing?
3) What are effective strategies and approaches to attaining high course grades in physics?

The importance of the first question above warrants attention; if it is firmly established that there is indeed a positive relationship between learning of physics concepts and course success, then the two can be treated as nearly synonymous for the sake of argument, which implies that one can reasonably make the assumption that a student’s course grade would be a reflection of their conceptual understanding. Furthermore, if this holds true, then it makes the second question easier to answer, especially with my given approach; instead of categorizing activities as strictly characterized by surface or deep level learning, I will inquire about the student’s level of conceptual understanding by asking about the percentage of exam-level problems that they fully understood before test day. This will better represent the student’s conceptual understanding in the course, contrary to assessing their preference with certain rigidly categorized activities. For example, if when doing practice problems, connections across concepts are made and the fundamentals are understood, I will consider this “deep” processing, although practice problems were strictly assumed to be a “surface” activity by the two reports done on physics students. Additionally, to answer the third question, my research will hopefully give insight into the most effective strategies for course success by gathering statistics on student grades to back up claims.
Assuming the positive link between deep understanding and course success is firmly established, this third question can be answered by student input on what increased their conceptual understanding most significantly, since it would then act as an agent towards a higher grade.

Located in the appendix of this paper, are my survey questions (66 respondents) and interview questions with students who scored grades in the A range (7 respondents). In order to maintain control and consistency in my results, all students interviewed and surveyed took the same physics course. As engineering students are typically more experienced with a broader range of physics courses, I decided to focus on them. The physics course I chose is specific to 1st year engineering students: “Physics 157: Introductory Physics for Engineers”.

Discussion

Limitations of the Research

Similar to the two previously cited studies done on physics students, I performed the surveys and interviews on students from a single physics course. However, given that my sample size is so small (66 respondents), it must be noted that further research would be needed to develop my claims presented. My new findings will hope to provide a new and developed area of inquiry, but of course it must be realized that this specific case may not be applicable to all the other broad ranges of physics courses out there, and that more research would have to be done to make larger generalizations with certainty; for example, the way students are tested in other physics courses may not always be the same. Furthermore, some students may not be able to accurately assess their own conceptual understanding when answering the survey and interview questions. However, since I will establish a link between course grades and conceptual understanding, I can use grades as a verifiable reference to minimize these potential distortions in
the data. My findings will hopefully be a stepping stone in providing answers to some questions previously left unchecked.

Clarifying Terms

In the following papers to be cited, “deep” understanding is clearly defined as a development of conceptual understanding (Elby 52 and Prosser, Walker, and Millar 47), and so “conceptual” and “deep” learning can be treated synonymously. Also, some interviewed students preferred not to have their percentage mentioned, but rather just their letter grade. An A- ranges from 80-84%, an A ranges from 85-89%, and an A+ is 90%+. All interviewed students scored marks in the A- to A+ range. Also, “practice exams” and “practice problems” will be used interchangeably, as this was the case in Physics 157.

The Relationship between Conceptual Understanding and Course Success

Research already done on physics students’ learning preferences has already suggested that conceptual understanding is viewed as less important by some students when it comes to course success. In “Another Reason Physics Students Learn by Rote”, students reportedly spend more time with formulas and practice problems, and spend less time with concepts and real-life examples, as concepts are not viewed as necessary for test performance (Elby 54). Elby collects data on students’ actual study habits in physics courses, and compares it to how these students say they should learn if their sole purpose was to learn physics more deeply (without being graded). Elby found that if students were not being examined, they would focus more on concepts and real-life examples, and less on practice problems. However, in Table I of Elby’s study, the statistics show that the least students agreed that a reduction of practice problems would be effective in learning deeply (54). Nonetheless, it still implies that a reduction of practice
problems is recommended for deep understanding. However, the report separately categorized these activities to imply no overlap; it makes the assumption that practice problems are unrelated to application of concepts and real-life examples. When a student selects that they should “focus more on concepts”, this may very well imply doing more practice problems. The survey was designed poorly to not account for this; in fact, if students were asked for techniques to better improve concepts and real-life examples, students may actually come to the realization that practice problems were most related to such issues. Since the survey does not ask students how they would practice concepts and real-life examples, students did not have to think about alternative methodologies to implement these goals, and it is difficult to say conclusively that the amount of practice problems performed should be reduced, since it could be highly linked to real-life examples, concepts, and the strengthening of that knowledge. Since Elby’s survey did not adequately account for such overlaps, this weakens the data he uses to suggest that conceptual understanding is not a necessary component of course success. By crafting a more appropriate survey, I found that conceptual understanding was actually very important to course success.

Rather than depending on statistics to draw conclusions from purely suggestive data, my approach was rather direct; I decided to ask students whether they believed a deep understanding was important for course success. In fact, of the 66 physics students who participated in my survey, 74% of students responded that conceptual understanding is “crucial” to course success, while only 26% deemed it “somewhat important”; this is already a majority response that contradicts the beliefs of the students in Elby’s study; if understanding is crucial, why not spend more time with concepts? When further filtering out the students who achieved a grade of over 90% (the top 15% of respondent achievers), 100% of these high-performing students responded that conceptual understanding is “crucial” to course success. Through a combination of interview
responses, it appears that conceptual understanding was crucial because students were required to apply physics concepts in order to solve unique exam problems. Sonny Cervienka, a student who scored an A in the course, describes that understanding is “key”, as it “allows you to solve complex questions not through prior experience but through ingenuity.” Sonny further explains how the final exam had “questions unlike any we had before, making relying on past examples not possible.” The importance of understanding is further echoed by all six other interviewed students, who shared similar views to Sonny. “Every question is different and so each answer requires a unique thought process and solution…to solve a question, it requires you to think if the answer is sensible – does it make sense in a real life situation?”, says Jessica Chapman, a student who received a 97% in the course. While the students in Elby’s study may believe that a deep understanding is not necessary to course success, statistics and the testimony of higher achieving physics students in Physics 157 would suggest otherwise; that a deep course understanding is indeed crucial.

With this new insight, it is reasonable to establish that in the case of Physics 157, strong course performance is very closely related to a substantial conceptual understanding. Thus, methods which increase conceptual understanding in physics learning would therefore be directly related to strong exam results. This means that by taking input from the higher achieving students of what increased their conceptual understanding the most, this would simultaneously tell us the best ways to learn physics deeply and the best ways to prepare for examinations. This will be further explored in the context of practice problems and strategic approaches.
The Relationship between Practice Problems and “Surface” and “Deep” Understanding

It is important to note that Elby and the authors that wrote “Students Perceptions of Learning Physics” all came to the similar conclusion that students preferred practice problems and familiarity with formulas, which both reports considered surface approaches. My survey and interview results are in agreement with the student preference for practice problems, but there is a glaring contradiction in the categorization of what is considered a “surface approach.” It was earlier established that students of Physics 157 agreed that a conceptual understanding is crucial for course success. However, if practice problems were a preferred strategy among the highest performers, it means they cannot be considered as a pure surface approach, since this would imply that no conceptual understanding is being developed by working through them. Therefore, rather than strictly categorizing activities into either “surface” or “deep” approaches and then gathering tallies of student results, I instead more accurately represented a student’s development of concepts by being, again, rather direct – asking if they believed such methods increased their conceptual knowledge. In this way, their final grade in the course would be an appropriate reflection of the weight of their response. The average of all the 66 participants in my survey was 79.8%, with 64% of students saying practice exams significantly improved their conceptual understanding, 30% saying they were only somewhat affected, and 6% saying not affected at all. Interestingly enough, when filtering out the top 15% of respondents who got 90%+ in the course (averaging 94%), 100% of these students said that practice exams significantly increased conceptual knowledge. This means that higher performing students found practice exams to be very helpful for success. Toren Dofher, a student who scored 91% in the course, explains this: “my most effective study strategy is to do tons of practice problems. I try to understand every
problem...It also improves conceptual understanding by showing you what can and cannot be done.” Jessica Chapman also gives insight into why practice problems are so helpful; “To be able to apply the concepts, in my opinion, is the best way to fully understand a topic...an application question cannot be fully answered without a complete understanding of the course material.” As the survey results show, and with explanations from interviewees, practice problems are undoubtedly effective for deep processing amongst the highest scoring students. But why does it seem to resonate most strongly with only the strong achievers? For instance, in the non-filtered survey, 36% of students still believed that practice exams were only “somewhat significant” in improving deep understanding. To these students, practice problems may likely be considered a surface level approach, in agreement with the classifications made by the two previously referenced physics studies. Clearly, this suggests that there is a difference in approach to practice problems by these two types of students, which should be explored.

Further analyzing the survey results, it may appear that there is a strong relationship showing that students who found the practice exams helpful, also understood more of the solutions relative to others. When filtering out the people who understood 84-100% of practice problems, the average was 86%, with 88% of students saying that practice problems strengthened conceptual knowledge significantly. Students who understood 95-100% averaged 89%, and all eleven of these students said that practice problems significantly strengthened knowledge. As understanding with the exams increased, so did the relative perceived helpfulness of the practice exams to course success. This could likely suggest that lower performing students found practice exams less helpful for deep learning because they were unable to figure out ways to understand the solutions. This then leads to the importance of another big question; what strategies can be used to better help a student understand a solution to a practice exam that they initially do not
understand? Since practice problems seem to suggest a strengthening of deep understanding, this specific question helps answer the overarching question of the best study strategies for examinations, which will be explored in-depth in the next section.

Relationship of Most Effective Study Strategies to Course Success

Since conceptual knowledge is strongly related to course success, what types of strategies are the most effective for improving concepts? Let us explore the popular strategy of practice problems and see how they can be approached in such a way that maximizes deep learning. One might want to argue that an increased understanding of each practice exam solution is mostly a product of innate ability rather than study strategies. Although this may hold some truth, one should not be so quick to assume that this gap is so evident. My survey showed that 57% of students would try for some amount of time and then “give up after a while” for problems they didn’t understand. Of the students who averaged 94%, 100% of them always persisted until they understood each solution they went through. This implies that one attribute of top students is not necessarily that they understood everything immediately, but that they found methods to figure out solutions. One could argue that a student who understood everything immediately could still have chosen “persisted until I understood everything,” since figuring out the solution would require minimal effort. However, in all interviews with students in the A range, high levels of effort, persistence, and problem-solving strategies were present. Because of this successful persistence among top performing students which clearly led to increased performance, it is worth an evaluation of their strategies.

I would first like to analyze the survey results that were collected from filtering out all twenty students who received an 85+ mark in the course. Of these students’ votes for their top 3 most effective ways to gain conceptual knowledge, 55% voted for the textbook, 50% voted for
being in lecture, 35% voted for online resources, and 100% for practice problems. Among the interviewed students, appeared some common trends to approaching practice exams; identifying the gap in the understanding, and filling this deficit by reading the textbook or searching online. Identifying the area of weakness was an important step, as Toren Dofher suggests to “use only notes that relate to the question to help with hard concepts. Reread the [specific] textbook chapter to build foundational knowledge.” Jessica Chapman will “identify which parts of the problem [she doesn’t] understand and then search for this topic”, either in the textbook or online. It should be noted that every interview respondent said that the textbook and online resources were the most effective in bridging conceptual gaps. These strategies were also among the highest voted strategies in the survey that I listed earlier. Strangely enough, being in lecture, which had a significant amount of votes in the survey, was not mentioned by any of the interviewees. Thus, it is hard to make any judgment on the effectiveness of lectures and more data from a larger sample size would have to be collected. It should be noted that as lecture styles vary from course to course, this may be a less significant statistic anyways, since it would be hard to apply this as a generalization to physics courses holistically.

One last theme that appeared in 57% of the interviews was repetition for familiarity. Chris Ng, a student who scored 99% in the course, describes his method of clarifying the problematic areas; “after completing a question I struggled with, I write down the key concept or method that I missed in the corner of my the page to remind myself...[so] I can refresh my memory.” He first emphasizes the importance of identifying the area of weakness, but then mentions how he will return to it later for review. This seemingly common approach is echoed by Bruno Abrao, who says he will often try to “solve [the problem] again [to] clear up any doubts.” In addition to identifying and strengthening areas of conceptual weakness, it seems that familiarity could be
another important part of the process which comes from some repetition; however, much more research would have to be done to explore this issue.

**Conclusion**

While my research agrees with the two previously cited studies on physics students in that students prefer practice problems, we diverge when assessing this relationship to deep understanding. By being more direct with my questioning approach and using student grades to verify claims, I more accurately represented this issue, establishing the importance of conceptual understanding to course success, and the importance of practice problems to deep learning. These groundings verified my initial suspicion that deep understanding, aided by practice problems, positively impacts course grades. However, I was unable to fully answer the question of the most effective strategies to approaching practice problems and deep learning, so although my research hopes to give insight into this issue, the data is not conclusive, but suggestive. In my assessment of this, the survey and interview results for these students in the A range totalled only 27 respondents; although some areas of commonality were evidently pointed out, it would take a much larger sample size to ground more significant claims. Despite falling short here, I was still able to successfully ground the importance of the relationship of practice problems and deep learning to course success, while giving evidence for why it would be naïve to automatically assume this is a product of innate ability. This hopefully gives significant groundwork for further exploration into effective study strategies within this context. With some of the emerging patterns I identified when assessing strategic approaches, this can hopefully give direction for future research into this topic, which could be used to develop, verify, or invalidate some of the suggestions made by my data.
Appendix

Survey Questions

1) How many of the practice midterms and final exam papers for Physics 157 did you do?

- Less than 10%
- Less than 50%
- 50% to 75%
- 75% to 100%

2) Of the practice questions that you did do, how many of them did you fully understand conceptually after looking at the solutions (that knowing the concept, you would be able to apply to confidently apply to a different problem)?

- Less than 50%
- 50% to 74%
- 75% to 84%
- 84% to 94%
- 95%-100%

3) Did doing the practice problems improve your conceptual understanding in any way? (Please read all yes options if you choose yes)

- No, I did not learn anything from doing practice problems
- Yes, but not significantly – not enough for me to confidently use it as a main source of test preparation
- Yes, it strengthened my understanding and knowledge of concepts significantly
- Other, specify:

4) If you didn’t understand a problem solution or a concept, what did you usually do?

- Give up on trying to understand it instantly
- Try to figure it out (ex. notes, textbook, friends, prof, etc) but if unsuccessful, would probably just move on
- Persisted till I finally understood it eventually (ex. notes, textbook, friends, prof, etc)
- Other (please specify)
5) In Physics 157, how important do you think it is to have a firm conceptual understanding in relation to success in the course and doing well on the exams?

-Crucial
-Somewhat important
-Not important

6) Checkmark any strategies that you found improved your conceptual knowledge MOST significantly (Max 3) – you may check as few as you’d like

-Class lecture slide notes
-Personal notes I took myself in class or at home
-Reading the textbook
-Finding online resources and videos related to the particular subject
-Being in class for lecture
-Doing in class lecture worksheets
-Doing practice problems (exams/tutorial homework)
-Other: specify

What was your final course grade in Physics 157? (Enter as a percentage)
Interview Questions

1) To perform well in Physics 157, how important do you think it was to have a strong conceptual understanding of the topics? Why or why not? (ex. How was the course tested, how does this relate to the importance or non-importance of conceptual understanding)

2) What resources, approaches, strategies, and study techniques do you think benefitted course grades the most? Explain why they were helpful or important (possible suggestions: talk in terms of study efficiency, familiarity, or conceptual understanding).

3) Of the above strategies, which ones did not enhance conceptual understanding? Why were these important in achieving high grades?

4) Do you think your knowledge was further deepened by practice problems? Why or why not? (ex. Did it help connect concepts…clarify misconceptions…or did it confuse you more and make things worse?).

5) How did you approach a problem that you didn’t understand? In other words, what would you recommend as a common technique/approach that you used to finally understand it. (If you usually give up instantly, you may skip this question).

6) What was your final course grade in Physics 157?
Works Cited

