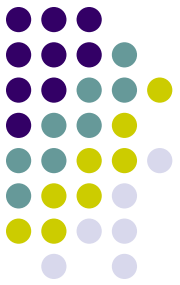


An Investigation of the Conceptual Presentation of Electricity and Magnetism Problems in Undergraduate Physics Textbooks



*This research supported in part
by NSF Grant DUE-0535928*



What we hope to find:

- How much conceptual coverage exists in standard textbooks?
- How does that coverage vary among the books?

The Textbooks

The seven textbooks used in this study were chosen for their frequency of use.

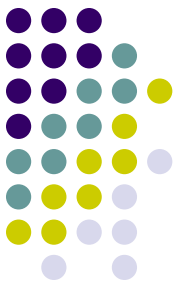


- Understanding Physics by Cummings, Laws, Redish, and Cooney (clup)
 - It is a calculus-based textbook developed by Physics Education Research
- Physics: Principles with Applications, Sixth Edition, by Giancoli (gp)
 - It is an algebra-based textbook.
- Conceptual Physics, Eighth Edition, by Hewitt (hcp)
 - It is a conceptual physics textbook.

The Textbooks



- Fundamentals of Physics, Seventh Edition, by Halliday, Resnick, and Walker (hrw)
 - It is a calculus-based textbook.
- Physics for Scientists and Engineers with Modern Physics: A Strategic Approach, by Knight (kp)
 - It is a calculus-based textbook developed by Physics Education Research.
- Sears and Zemansky's University Physics with Modern Physics, Eleventh Edition, by Young and Freedman (yfu)
 - It is a calculus-based textbook.
- Sears and Zemansky's College Physics, Eighth Edition, by Young and Geller (ygc)
 - It is an algebra-based textbook.



The Problems

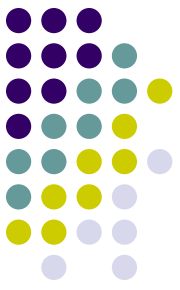
- All of the conceptual problems were identified in the electricity and magnetism portions of the textbooks, excluding the optics problems.
- A strict definition of the term “conceptual problem” could not be determined.
 - As a result, two researchers worked independently, identifying the conceptual problems appearing in the textbooks chosen for the study.

Writing the Problems

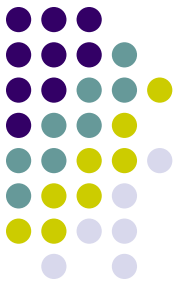


- Each unique problem identified in the textbooks was written along with its solution.
- If a problem was identified which was identical to another problem existing in the database, the subsequent problem was not written. The repeat problem was associated with its identical problem, and the two were treated the same during analysis.
 - The first researcher found all of the problems that *might* be considered conceptual, excluding only those problems she considered without a doubt non-conceptual.
 - The second researcher found only those problems he considered to be undeniably conceptual.
 - As a result, the first researcher identified 303 more conceptual problems than the second researcher.
 - These problems were categorized as belonging to the spectrum of problems between unquestionably conceptual problems to non-conceptual problems.

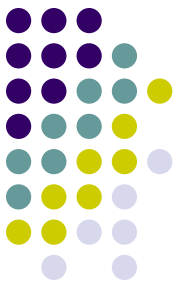
- The selected problems were made abstract before they were written.
- Many problems in the textbooks contained multiple parts, and the parts were maintained when the problems were written for this study.
- Each problem's solution was written using the physics introduced prior to the problem's appearance in the textbook.
- A second researcher checked each problem's solution for accuracy and value in instruction.
- A third researcher verified the problem-collection process by acquiring his own set of conceptual problems from the same source.



Solution Primitives



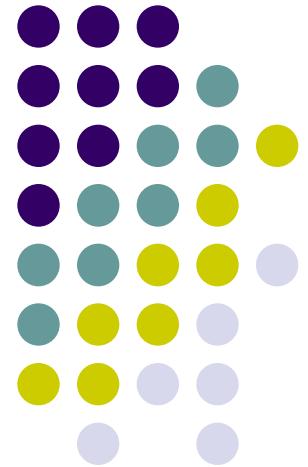
- This project attempted to characterize the number of and variability of conceptual problems and examples in a set of prevalent textbooks.
 - Quantifying the conceptual complexity of a problem proved to be difficult. The solution to a single part could vary from a simple single-sentence solution to one occupying most of a page.
 - To overcome this difficulty, idea of a “solution primitive” was introduced.
 - A solution primitive was defined to be the smallest separable but independent part of a solution, and it must be able to stand alone as the answer to another, smaller problem.



- A solution primitive identification protocol was developed after some experimentation.
- To test the identification of solution primitives using the protocol, three researchers each marked the solutions to 30 conceptual and non-conceptual examples with solutions found in three physics textbooks. An 83.9% agreement was found among the researchers, and the error for the total number of solution primitives identified per researcher was found to be 5.8%.
- The solution primitives in the database were marked by a single researcher, so an error of 5.8% should be expected.

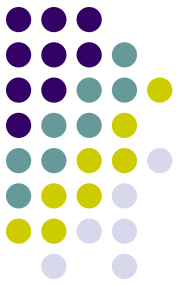
Question Primitives

A question primitive was defined to be the question that a solution primitive answers.



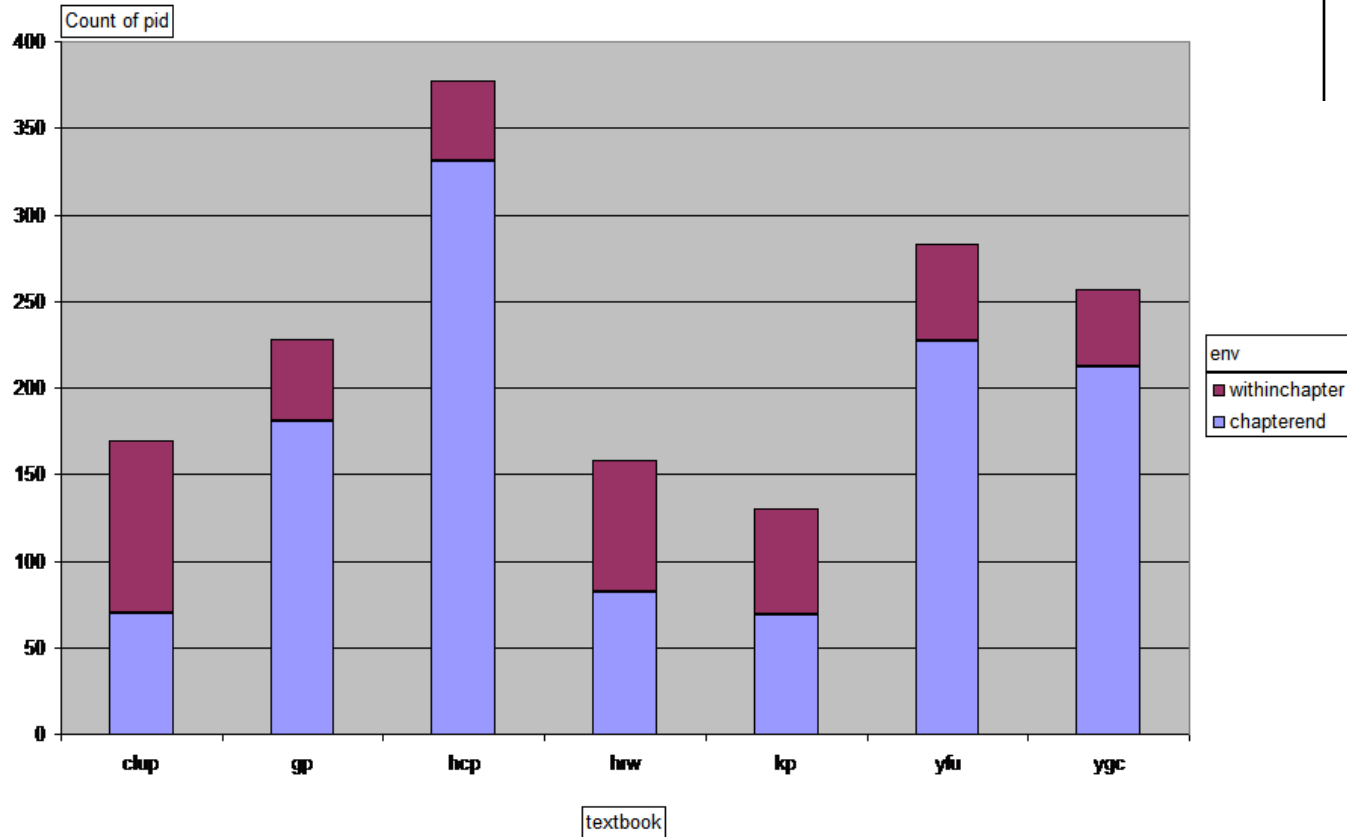
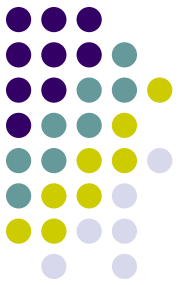
Problems Identified by Source

Among the sources, the largest number of problems was found in hcp, and the least number of problems was identified in kp.



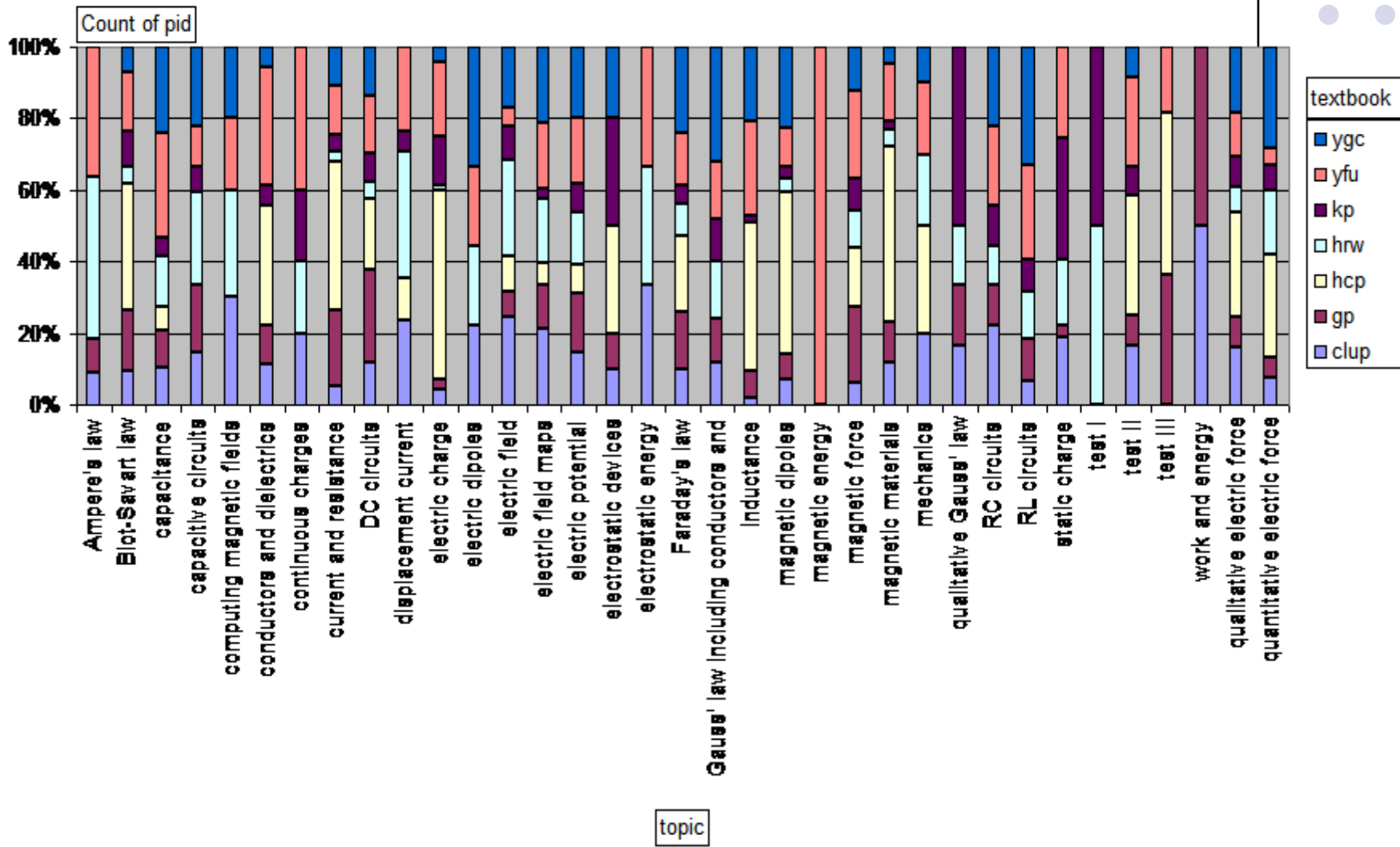
Textbook	Problems Written	Identical Problems	Total Problems
clup	123	46	169
gp	215	13	228
hcp	341	36	377
hrw	115	43	158
kp	104	26	130
yfu	246	37	283
ygc	225	32	257
Total	1369	233	1602

Problem Environments

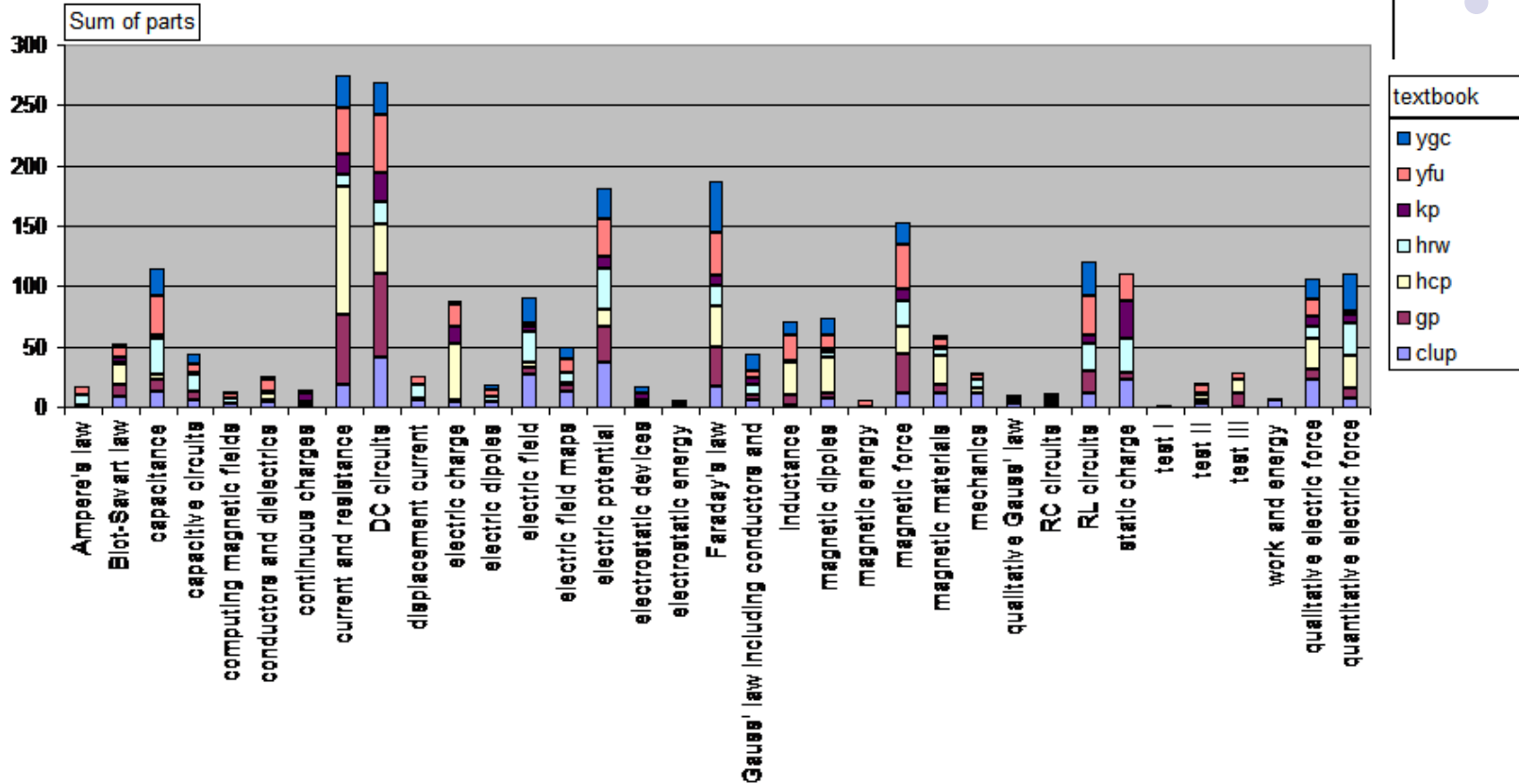


- Most textbooks have huge numbers of conceptual problems located at the chapters' ends, but hrw and clup divide the conceptual problems almost evenly between the chapters' bodies and the chapters' ends.

Problems by Topic



Parts Per Topic



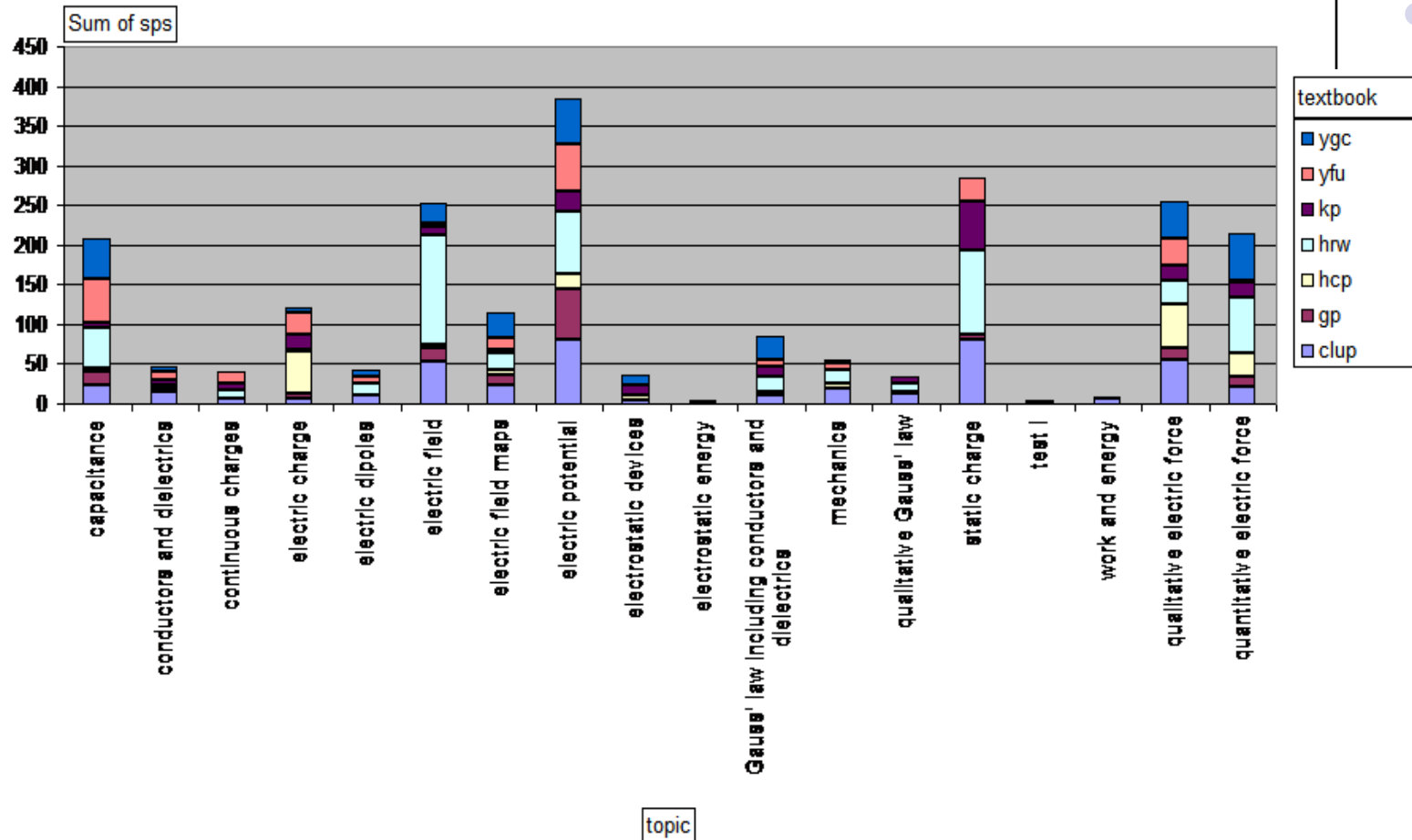
topic

- Note the huge number of parts of problems covering current and DC circuits and the miniscule number of problems pertaining to magnetic energy.

Solution Primitives Per Topic



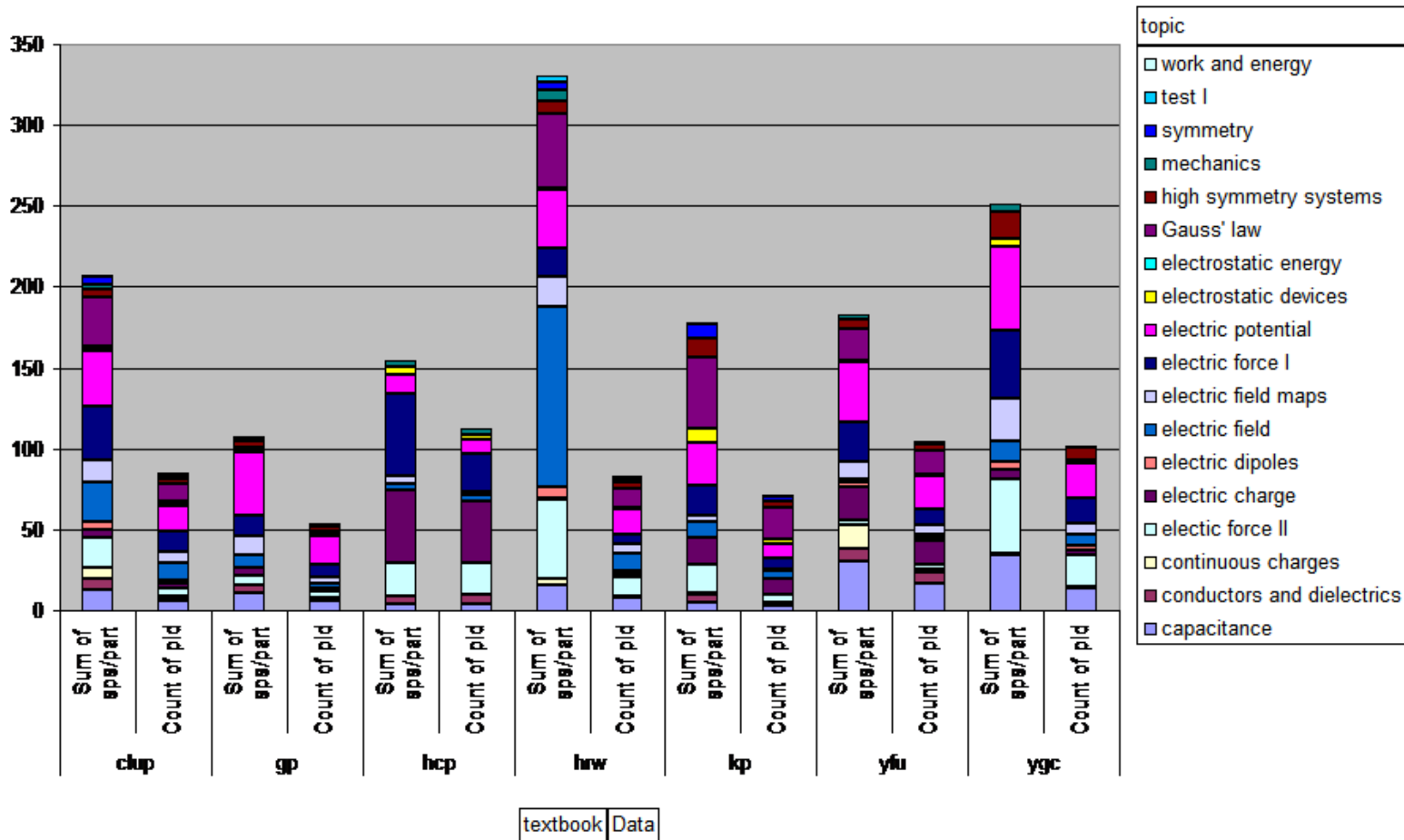
SPs Per Topic (Restricted)



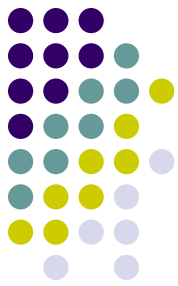
- Of the topics used in the study of solution primitives, electric potential seems to have the most coverage.

Solution Primitives Per Part

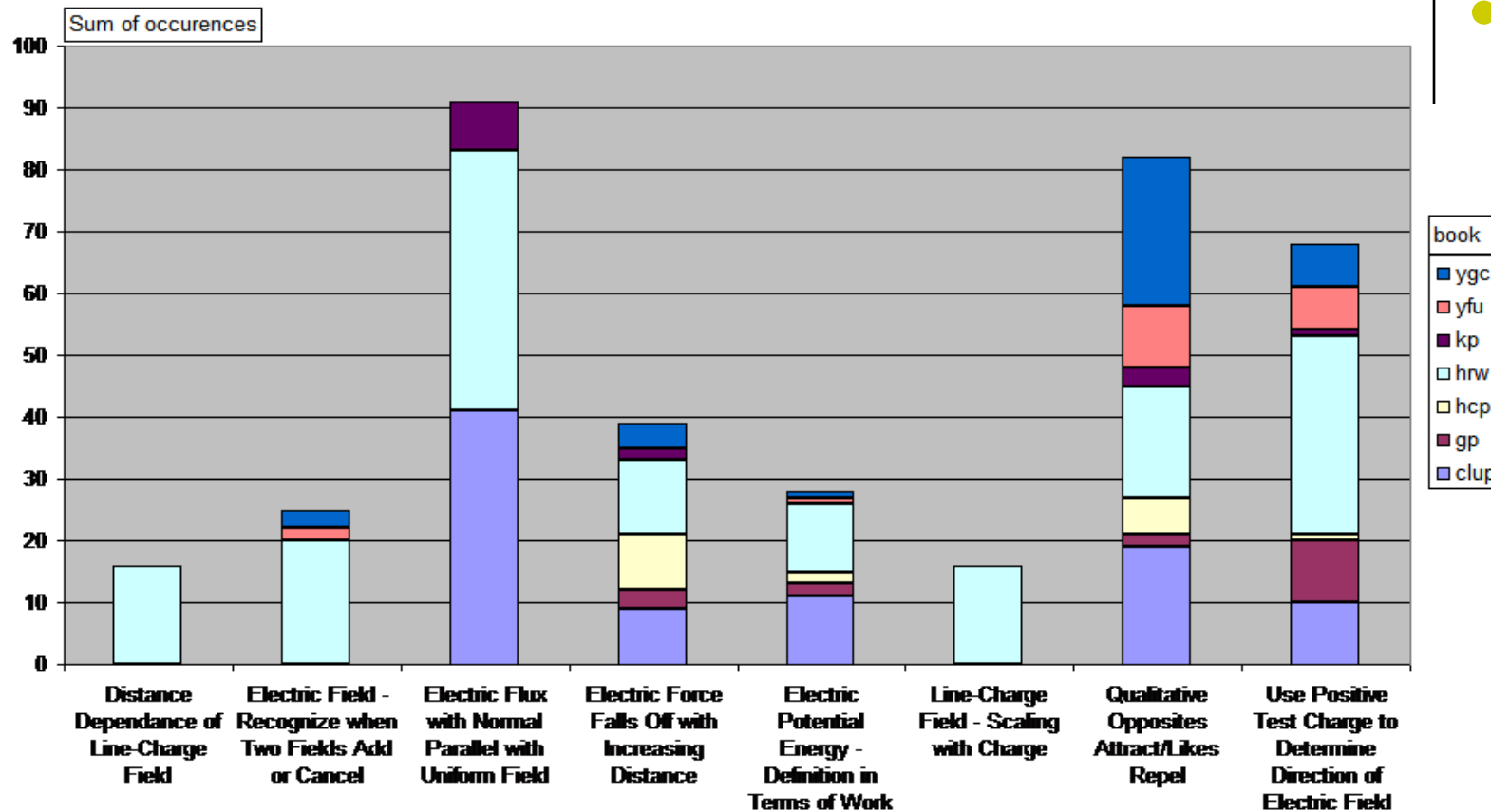
Comparing the Sum of SPs/Part With Number of Problems



- A larger difference between the sum of sps per part and the count of pids denotes a higher difficulty. Notice that algebra-based ygc appears to have a higher level of difficulty than calculus-based yfu.

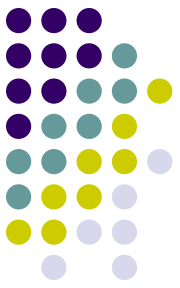


Question Primitives by Textbook (Preliminary Study)



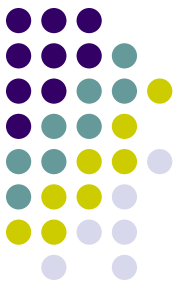
sp

In the topics through capacitance, a total of 583 question primitives were identified. The above shows some of the most common solution primitives and the distribution among the textbooks.



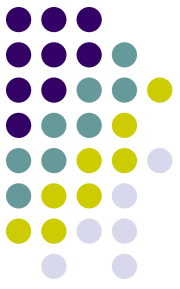
Discussion

- Most of the problems acquired for this study originated in hcp, but the problems in that textbook tend to be simpler than those found in most of the other books used.
- The problems and parts found in clup and hrw are spread consistently between the chapters' bodies and the chapters' ends.
- The textbooks with the most conceptual complexity are hrw and clup. These books have the greatest number of parts per problem and the largest number of solution primitives.
- The least bias shown towards current and DC circuits was by hrw and clup, and the most bias was shown by gp and hcp.



Conclusion

A quantitative analysis of seven undergraduate physics textbooks was performed by assessing and categorizing the conceptual problems, parts, and solution primitives identified in the books. A large variation in conceptual coverage was found in these textbooks. Strong variation was found in the number of problems per book, the distribution of problems by topic, and the average complexity of the problems.



Future Research

- In the future, conceptual-problem identification will be further studied to establish a precise definition of the term “conceptual problem.”
- The differences in the identification of conceptual problems by individual researchers will be used to study the spectrum of problems that can be categorized as belonging to the gray area between quantitative and purely conceptual problems.
- Question-primitive marking will be verified, and the question primitives in the seven textbooks will be studied in more detail.