

Conceptual versus Computational Homework

Kristi Concannon



King's College, PA

ABSTRACT

Does the type of homework assigned in an introductory physics course affect exam performance? In Spring 2014, two sections of algebra-based second-semester introductory physics were taught by the same instructor. Class-time for both sections focused primarily on building conceptual understanding, with minor emphasis on the mechanics of problem solving. End-of-chapter problems were assigned to each of the two sections: Section A was assigned 8-10 conceptual exercises; Section B was assigned 2-3 computational problems. The alternate problem sets were recommended to students, but were not collected for grading. Three exams and a comprehensive final exam were given, each evenly weighted with conceptual and computational problems. We anticipated that (1) students in the section requiring conceptual homework would perform better on conceptual exam questions than students required to submit computational homework and (2) students in both sections would perform equally well on the computational exam problems. This poster will present our findings.

EXPERIMENTAL DESIGN

Students attended four 50-minute class periods per week. Class time was divided between traditional lecture, peer instruction questions and class exercises. Students were assigned textbook-based homework (from Knight, *Physics for Scientists and Engineers: A Strategic Approach*, 3rd Edition, Pearson) on a weekly basis and online homework through MasteringPhysics™ three times per week.

Students in both Section A and Section B gained experience analyzing physics problems conceptually and computationally in a variety of methods as outlined in Table 1. Besides the assigned homework to be completed for grading, all other aspects of the course were identical.

| Table 1: Example Activities | Conceptual | Computational |
|-----------------------------|---|--|
| Lecture Activities | <ul style="list-style-type: none"> Clicker Questions Peer Instruction | <ul style="list-style-type: none"> Instructor Examples |
| Class Exercises | <ul style="list-style-type: none"> Workbook Problems E&M TIPERs Ranking Tasks | <ul style="list-style-type: none"> Group Practice Problems |
| Homework Problems | <ul style="list-style-type: none"> Mastering Physics "Tutorial" Problems End-of-Chapter "Concept Questions" (assigned to Section A) | <ul style="list-style-type: none"> Mastering Physics Problems End-of-Chapter "Exercises" (assigned to Section B) |

SECTION COMPARISON

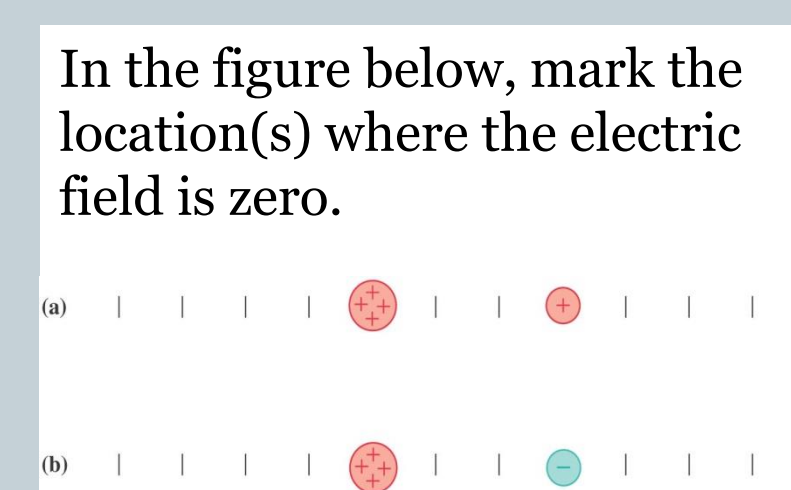
Table 2 shows that the academic experience and ability of the students in Section A and Section B were not significantly different; students in each section had completed similar numbers of credits and had nearly identical mean cumulative GPAs. Section B was just over half the size of Section A.

Students in Section A reported a higher level of investment in the course than did students in Section B. Table 2 summarizes the post-course survey responses of students to questions examining the likelihood of completing additional problems and exercises beyond those assigned.

| Table 2: Comparison of the Two Sections | | |
|--|-----------|-----------|
| | Section A | Section B |
| Total Students Enrolled | 36 | 21 |
| Mean Cumulative GPA of Students in Section | 3.266 | 3.280 |
| Mean Credits Completed by Students in Section | 90.1 | 88.2 |
| % of students who self-classify as engaged in class "always" or "most" of the time | 60.6 | 76.2 |
| % of students who claim to complete the entire practice problem packet "most of the time" | 84.8 | 61.9 |
| % of students who claim to complete the recommended homework problems "always" or "some" of the time | 54.6 | 42.8 |
| % of students who claim to complete additional MasteringPhysics problems "most" or "some" of time | 60.6 | 42.8 |
| % of students who claim to "always" complete the problems in the exam review packet | 81.8 | 76.2 |
| % of students who claim to spend more than 2 hours studying per week | 60.6 | 42.9 |

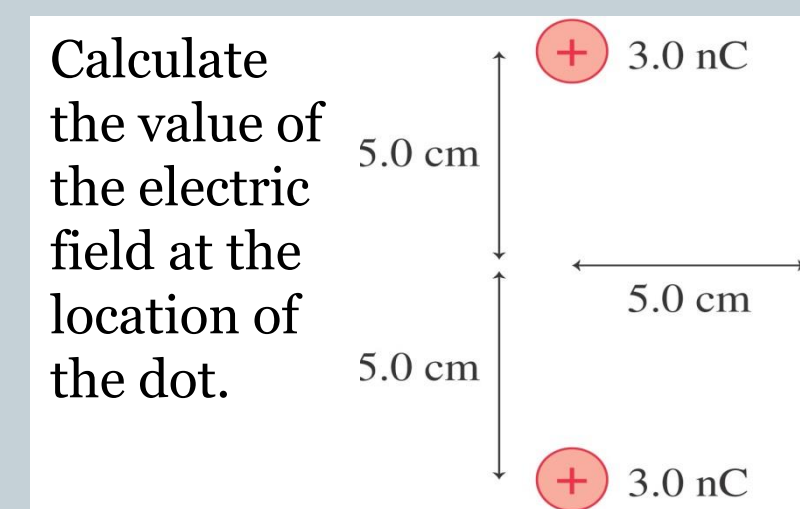
PROBLEM COMPARISON

An example of two assigned homework problems is shown below. Each problem requires students to work with the same fundamental idea – the electric field produced by point charges – but to approach the idea from either a conceptual or computational framework.



In the figure below, mark the location(s) where the electric field is zero.

Conceptual Problem (Section A)



Calculate the value of the electric field at the location of the dot.

Computational Problem (Section B)

RESULTS

Table 3 shows the exam average and standard deviation for Section A and Section B on each of the three exams and the cumulative final exam. Averages were computed separately for the conceptual and computational exam questions. The results of two statistical comparisons are also shown.

Table 3: Average Exam Scores

| Average Exam Scores - Conceptual | | | | |
|----------------------------------|-------------|-------------|---------|--------|
| | Section A | Section B | P-Value | T-Test |
| Exam 1 | 64.6 ± 16.9 | 68.2 ± 15.1 | 0.422 | 0.789 |
| Exam 2 | 67.6 ± 12.3 | 70.2 ± 12.3 | 0.438 | 0.786 |
| Exam 3 | 78.7 ± 11.6 | 82.2 ± 12.2 | 0.299 | 1.068† |
| Exam 4 | 66.7 ± 16.1 | 71.4 ± 12.9 | 0.229 | 1.157† |

| Average Exam Scores – Computational | | | | |
|-------------------------------------|-------------|-------------|---------|--------|
| | Section A | Section B | P-Value | T-Test |
| Exam 1 | 72.2 ± 17.7 | 77.0 ± 16.7 | 0.321 | 0.993† |
| Exam 2 | 61.7 ± 24.3 | 75.8 ± 18.3 | 0.017* | 2.305‡ |
| Exam 3 | 76.7 ± 16.1 | 83.7 ± 10.3 | 0.05* | 1.778‡ |
| Exam 4 | 67.1 ± 17.0 | 72.2 ± 15.0 | 0.241 | 1.156† |

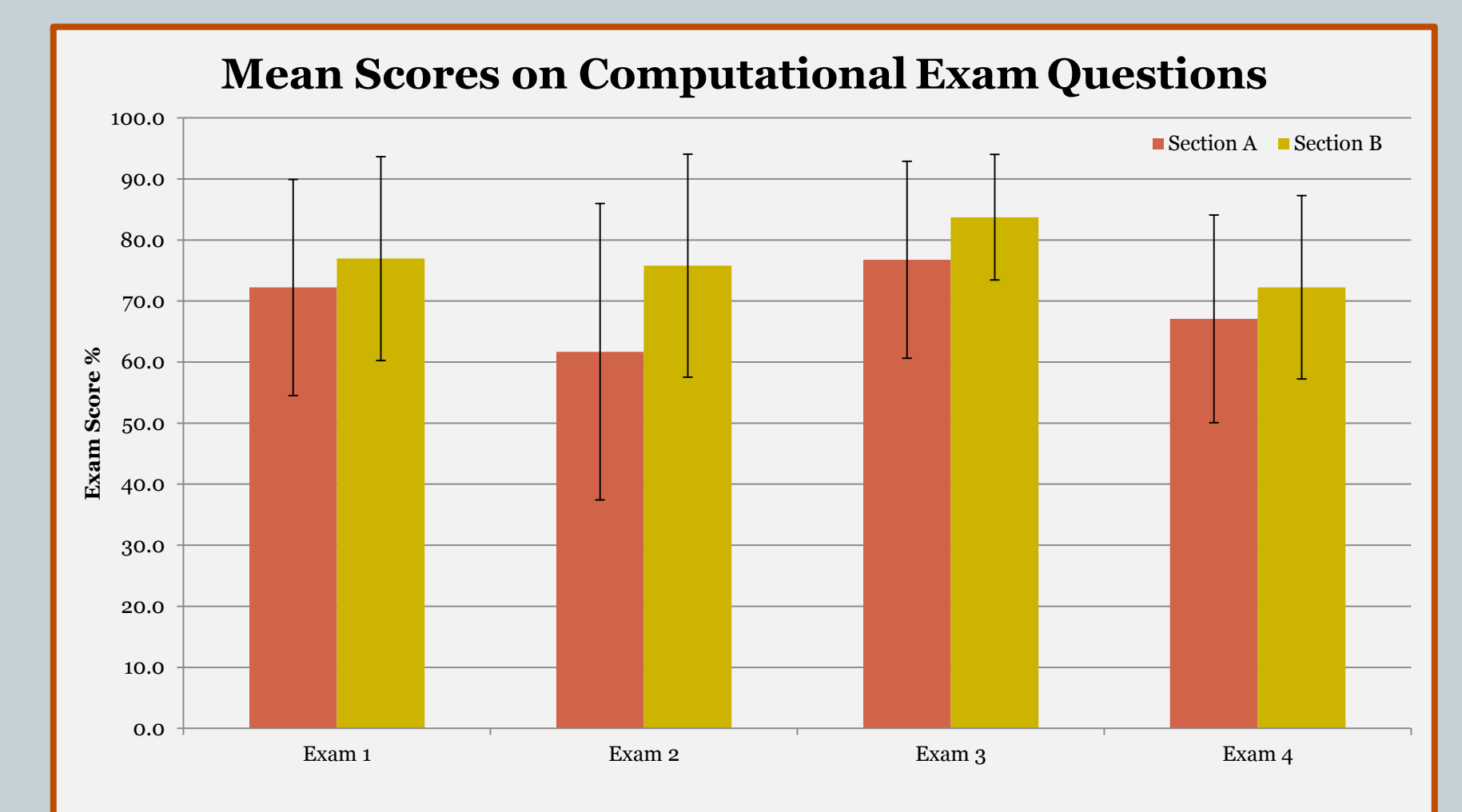
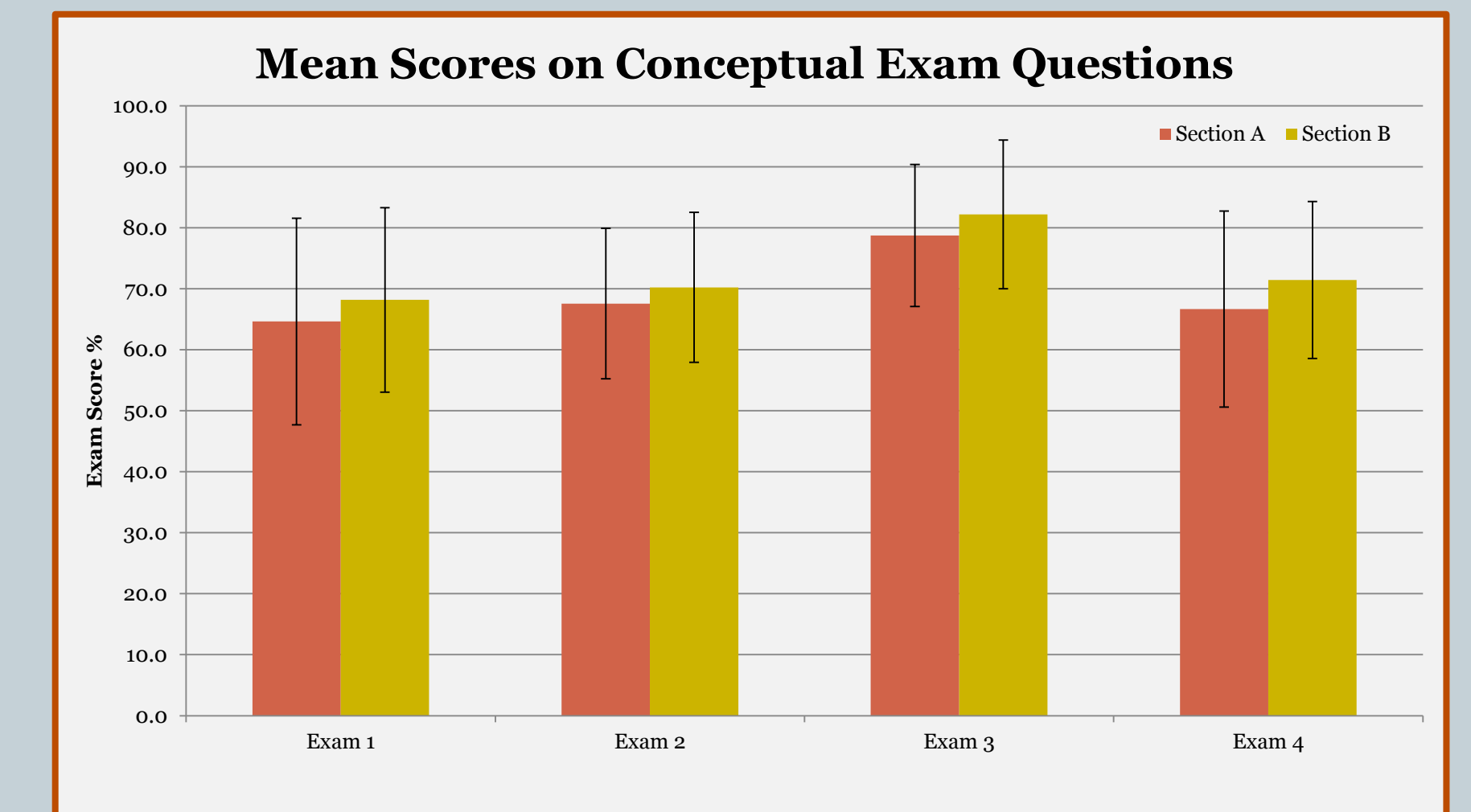
*Statistically significant when $p < 0.05$
 † Greater than 70% confidence level. ‡ Greater than 90% confidence level.

EXAM COMPOSITION

The summary below shows the breakdown of exam content for each of the three exams and the cumulative final exam. The breakdown of each exam is shown below.

| | | |
|--------|---|-------------------------------------|
| Exam 1 | <ul style="list-style-type: none"> Travelling Waves Standing Waves Wave Optics Ray Optics | 44% Conceptual 56% Computational |
| Exam 2 | <ul style="list-style-type: none"> Electric Forces Electric Fields Electric Potential Electric Potential Energy | 52% Conceptual 48% Computational |
| Exam 3 | <ul style="list-style-type: none"> Current and Resistance DC Circuits Magnetic Fields and Forces | 38% Conceptual 62% Computational |
| Exam 4 | <ul style="list-style-type: none"> Cumulative Final | 28% Conceptual 72% Computational |

Based on the exam content, the computational problems on Exam 2 – primarily vector arithmetic – were likely more challenging for students than the computational problems on the other exams.



CONCLUSIONS

On conceptual exam questions, students performed (statistically) equally well, regardless of whether they were assigned conceptual or computational homework problems. All students appear to get adequate reinforcement of concepts in other course components, independent of their assigned homework problems.

On computational exam questions, students who were assigned computational homework problems tended to score higher than those students who were assigned conceptual problems. The exam scores were markedly different on Exam 2, perhaps the most mathematically challenging of the four exams, and on this exam in particular, students in Section A scored an average of 15% lower than students in Section B. For Exam 2, the range in exam scores for Section A covered a 24 point standard deviation, indicating that some students could have benefitted from the additional computational homework. The weaker exam performance of Section A students is also interesting given that these students claim to have spent more time doing additional course work than students in Section B. However, only half of the students report regularly doing the recommended computational homework problems.