USING COMPUTER-ASSISTED PERSONALIZED ASSIGNMENT SYSTEM IN A LARGE-ENROLLMENT GENERAL PHYSICS

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Abstract

The on-line tutoring system, LON-CAPA, was implemented in Introductory Calculus-Based Physics-II course at Colorado School of Mines in fall 2008 and spring 2009. In this paper, the features and the case study of the LON-CAPA implementation were described. The performance data obtained from the scores of students enrolled in the course represented students' lower performances on written assignments and exams relative to LON-CAPA problems. The outcome could be students' insufficient problem solving abilities which arises because of poor knowledge of fundamental concepts. To overcome this drawback, an alternate technique to the LON-CAPA questioning method was designed. The technique is intended to increase the students' problem solving skills with a better conceptual understanding by using three integrated problem solving strategies which was incorporated with LON-CAPA type problem. If developed problem solving strategy steps can be introduced into the LON-CAPA problem, it is expected that students also will become experienced problem solvers.

Keywords: LON-CAPA; Problem Solving; Studio Physics

Introduction

To achieve success, students need to develop two habits. The first and more important is a regular active study of the material. The second, which helps a student enormously, is collaboration, cooperation, and discussion of the subject with other students (Cooper, 1995). In addition, students benefit from rapid formative feedback of their progress. Given the number of students involved these needs raised significant logistical concerns. One problem is that it is easy for students to get lost in the crowd and considerable care has to be taken to cater for the needs of the individual. For the instructors, the administration of examinations and problem sets can be almost overwhelming; the manual grading of the latter places a heavy load on teaching assistants and it is impossible for them to provide results rapidly enough for effective feedback. A computer-based learning support system is one of the realistic ways to meet these demands (Hunter, 2000).

There are many web-based educational tools available today that can be used in various ways. Some merely assist in managing traditional lecture courses, supplement the presentation of some of the material (e.g. Author ware-based visualization), provide question management and test construction (e.g. Question Mark Designer), or enable instructor-student conferencing on-line (e.g. AltaVista). Other tools (WebCT, Web Assign, etc.) enable entire web-based courses for either local or distance learning (Kashy et al., 1998; Hunter 2000).

One of the web-based educational tools is LON-CAPA. LON-CAPA (The Learning Online Network with a Computer- Assisted Personalized Approach) is the combination of a course management system, an individualized assessment system, and a learning resources management system. LON-CAPA is an integrated system developed to create individual assignments for students in quantitative or semi-quantitative subjects (Kortemeyer et al., 2001; Morrissey et al., 1995). It is a tool that relies on modern networked computer technology, and its success in a particular setting clearly depends on the skill and dedication of the instructor who must create the problem sets. This networked software system is a tool that enables instructors to write and distribute personalized problem sets, quizzes, and examinations for their students and includes an array of course management and statistical functions. The principal goals of LON-CAPA system of directed problem solving are to;

a) provide students with timely feedback on problem solving
b) minimize the continuous judging and ranking of students during the learning process
c) reward diligent work and encourage students to work together to develop skills
d) reduce the impersonal nature of instruction in a large college class
e) produce a system without tedious grading of individual assignments that can be scaled to large classes.

LON-CAPA enables entire web-based courses for either local or distance learning. The system provides a large variety of conceptual and quantitative problem functionality for personalized assignments, quizzes, and examinations (Kashy et al., 1993; Kortemeyer et al., 2008; Morrissey et., 1995). The sophisticated LON-CAPA includes three parts; *Quizzer:* to create questions and prepare personalized problem sets or examinations, *Grader:* to record student responses and scores, *Manager:* to create class reports and compile various statistical information which is available with a detailed description of the LON-CAPA (Hunter, 2000).

The features of LON-CAPA can be listed as follows:

1) A framework capable of delivering personalized assignments.
2) As remarked in Figure 1, content independent, the content is supplied by the instructor.

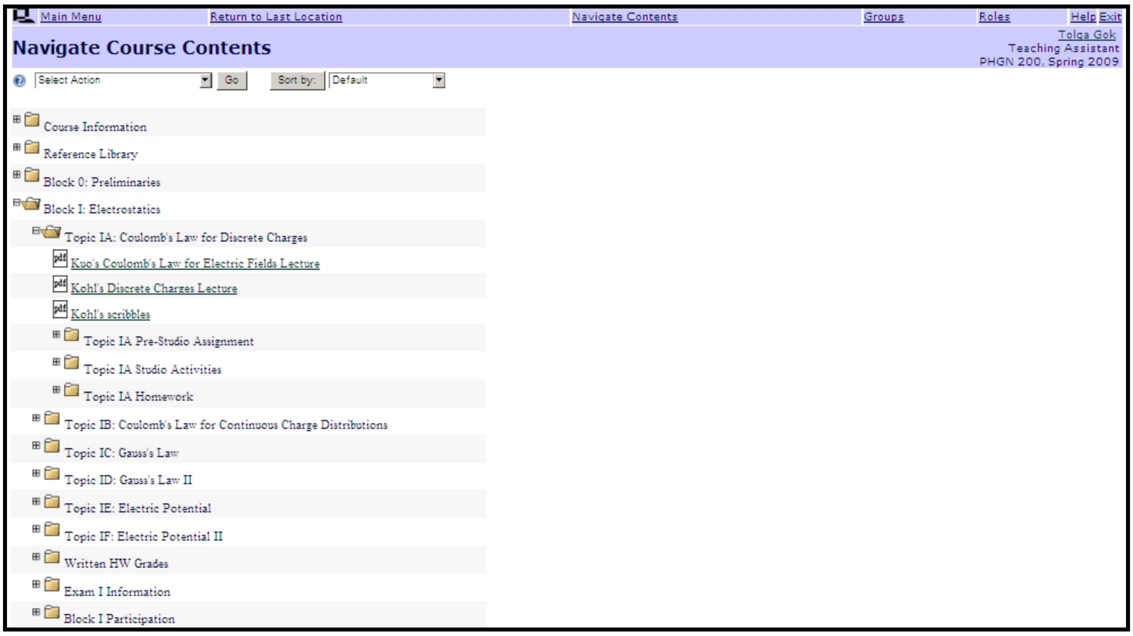

Figure 1: Course content for Introductory Calculus-Based Physics (ICBP-II) course

3) Web interfaced, each student had a personal user number, and for each exercise sheet there was a LON-CAPA-id consisting of various digits. The students could retrieve their LON-CAPA-ids from the system (Fig. 2).

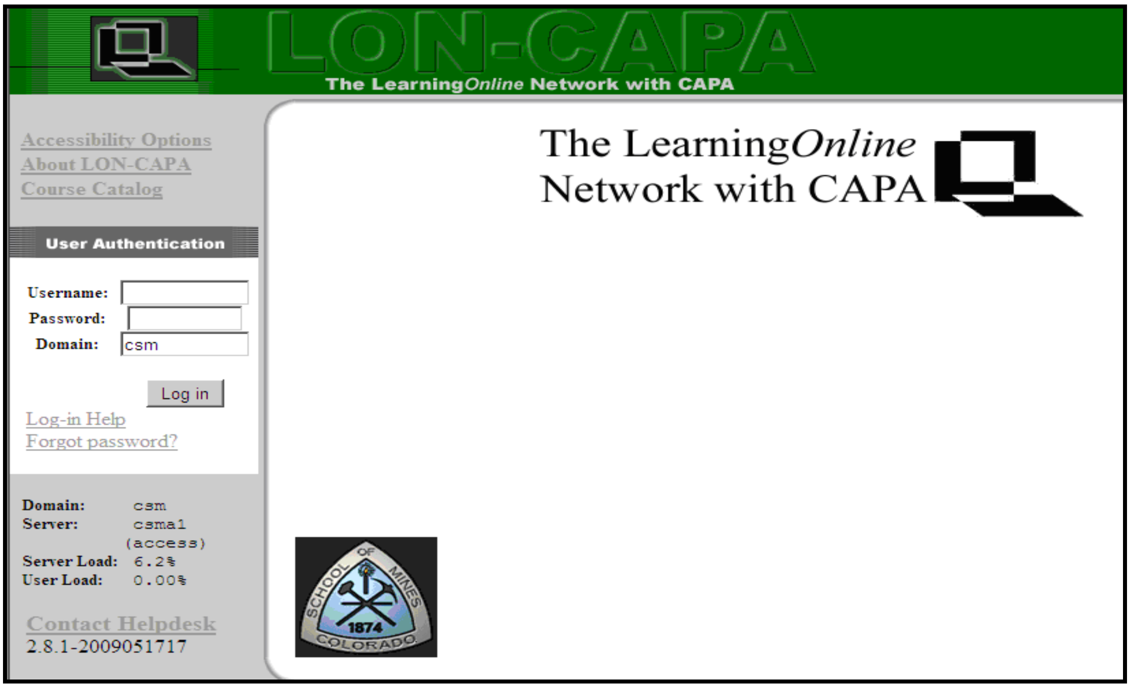

Figure 2: The LON-CAPA-username and password (id) of each student

4) Asynchronous-allowing students to pursue the assignments at their preferred time – schedule, subject to the constraint of due time.
5) Immediate feedback is provided to the students on their performance.
6) The system comes with a web forum (Fig. 3) that is useful in improving collaboration between the students and provides the instructor feedback on how well the students are doing.

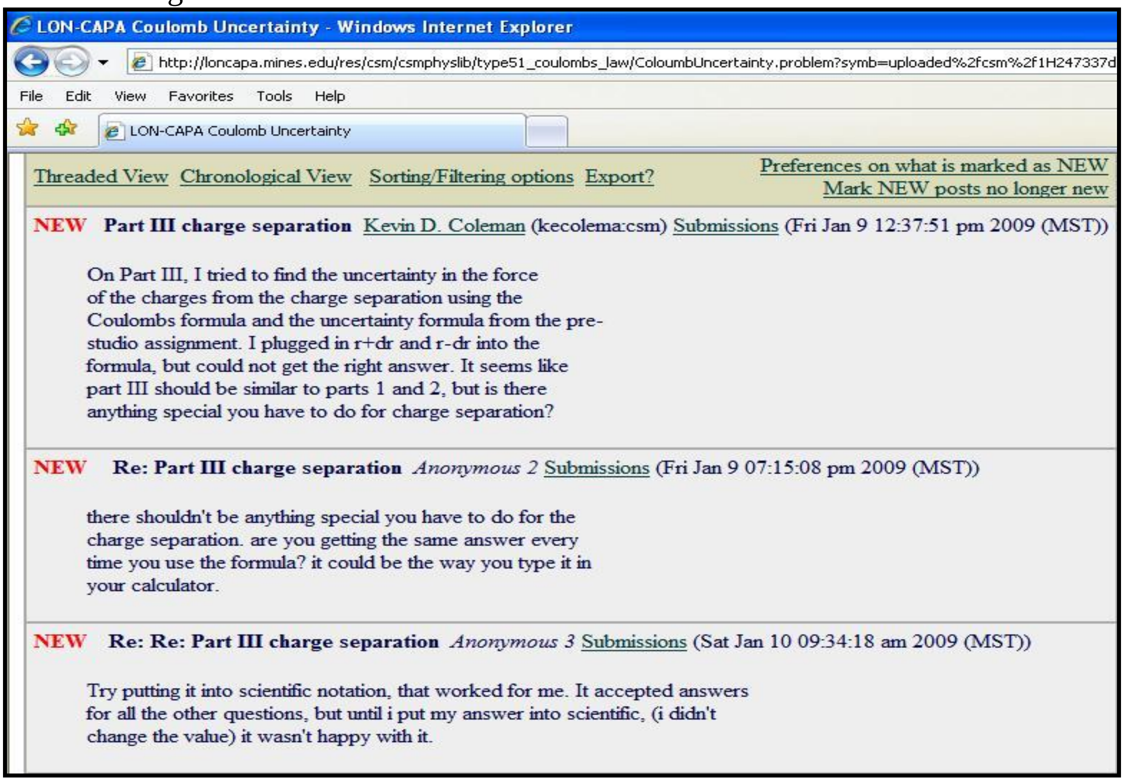

Figure 3: Web forum (improve collaboration and communication between students)

7) A useful tool is a report assigning a measure of difficulty to each of the problems. This provides the lecturer with real-time feedback on what is well understood and what is not, so she/he can take corrective measures immediately.
8) Various statistical analyses, can be readily obtained and provide real-time feedback.
9) Each student receives the same problem but with different numerical data, or different questions to answer (Fig. 4). These features promote cooperation and discussion among students while rendering mechanical copying much less likely. There are several problem types; a) multiple-choice and short answer problems, b) multiple-choice multiple response problems, c) representations-translation problems, ranking-tasks, d) context-based reasoning problems, e) estimation problems, f) qualitative problem, and g) essay problem.

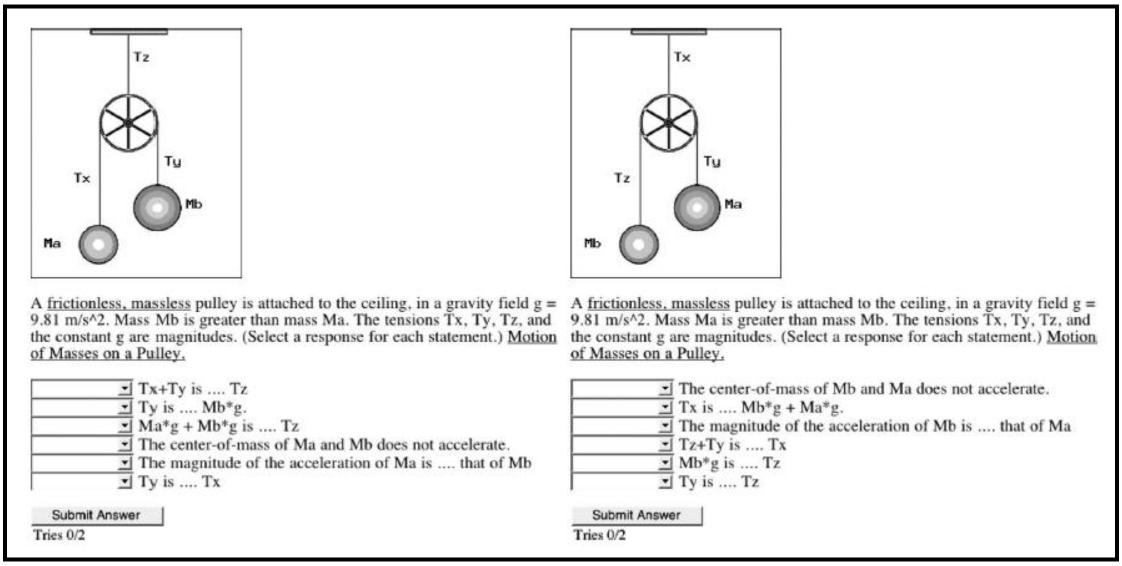

Figure 4: Web-rendering of the same LON-CAPA problem for two different students.

10) Each problem can be tried several times. 99 tries for below problem (Fig. 5) was given to students.

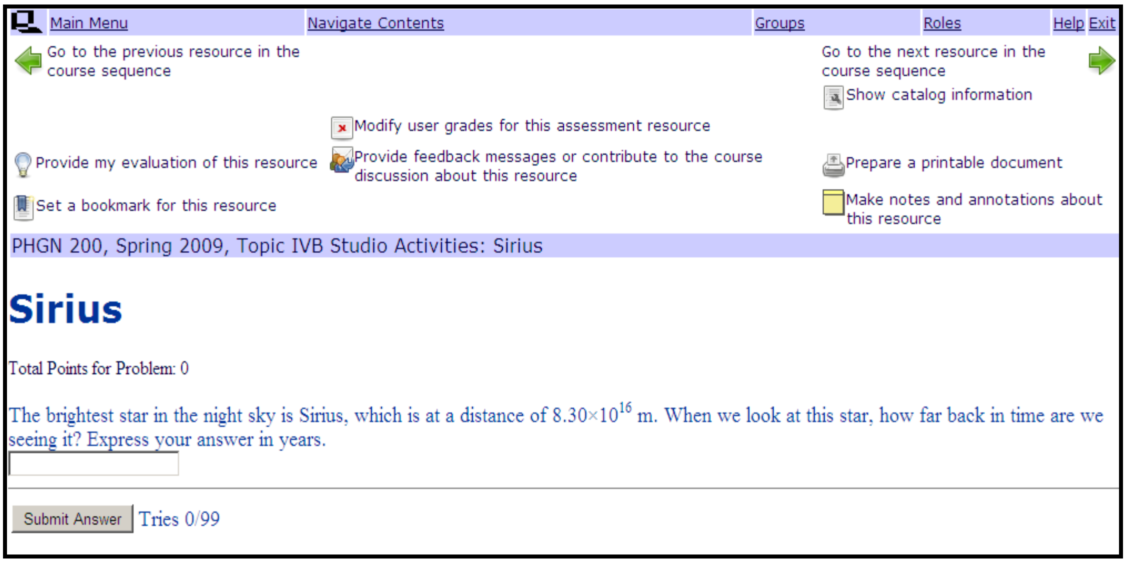

Figure 5: The number of tries (99) for problems (usually)

11) It is possible to build the problems so after a few wrong answers; there will be a hint or a short explanation.

LON-CAPA, while similar to many others (WebCT, Web Assign, WWWAssign, etc.) in most aspects, differs in three important ways:

1. The first is its capability to randomize problems, both algorithmic numerical exercises as well as problems that are qualitative and conceptual, so numbers, options, images, graphs, formulas, labels, etc., differ from student to student (Kashy et al., 1995). The students can thus discuss the assignments, but cannot simply exchange answers.
2. The second is in the tools provided that allow instructors to collaborate in the creation and sharing of content in a fast and efficient manner, both within and across institutions, thus performing the first goals of the WWW. Most of course management systems are built around the course as the main entity, and learning content is then uploaded to the courses. At the end of the semester, most systems allow export of the content to an instructor's personal computer, and then need reuploading in another semester. Within LON-CAPA, content is stored independently of a specific course in a shared cross-instructional content pool.
3. The third is its one-source multiple target capabilities, that is its ability to automatically transform one educational resource, for example a numerical or conceptual homework question, into a format suitable for multiple uses: the same code, which is used to present problems for on-line homework, can also create them for an on-line examination, or for a printed version suitable for a proctored bubble sheet examination which is later machine scored (Kortemeyer et al., 2005).

Previous studies on LON-CAPA examined the students' conceptual learning with FCI (Force Concept Inventory) (Hoellwarth et al., 2005), FMCE (Force and Motion Conceptual Evaluation) (Cummings et al., 1999), and CSEM (Conceptual Survey of Electricity and Magnetism) (Kohl and Kuo, 2009). This study presented detailed investigation on LON-CAPA students' performances in Introductory Calculus Based-Physics throughout two semesters (Fall 2008 and Spring 2009). The performances (LON-CAPA homework, written homework, LON-CAPA problems, and exams) of the students taught by LON-CAPA have not been elucidated in the open literature as of 2010.

Method

In the present study, brief information of LON-CAPA interactive learning and teaching environment was reported. Also the contribution of LON-CAPA to students` performance in Introductory Calculus-Based Physics II was investigated and discussed with students` scores for LON-CAPA Homework, Written Homework, exams, and LON-CAPA problems throughout two semesters (Fall 2008 "F08" and Spring 2009 "Sp09") semesters. The average scores of the students enrolled in ICBP-II were calculated based on the grade taken from Block I (Electrostatics) to Block IV (Optics) for each semester.

The investigation was conducted with Hybrid Studio Format "HSF" (Lecture/Recitation/Studio Physics/LON-CAPA) in the ICBP-II for two semesters. ICBP-II introduced the fundamental ideas of physics to students including electrostatic, circuits, magnetics, and optics. The basic goal of this course was: to understand the fundamental laws of electromagnetism as summarized in the Maxwell equations and related concepts and principles, to be able to apply these laws with the fundamental laws of motion using calculus, to construct a suitable understanding of the electromagnetic properties of physical systems in an applied context, and to begin to develop critical problem solving strategies.

At the Colorado School of Mines, each semester, the students were divided into three class sections, were taught by two instructors, followed the same syllabus (see Table 2), submitted assignments individually, and took common exams. A standard course design including daily lectures, in-class activities and solutions, homework assignments and solutions, and reading assignments is provided by a course supervisor for use by all instructors.

Hybrid Studio Format consisted of two one-hour lectures per week, and two two-hour blocks of studio time. Course material was separated into two-day blocks, where new principles were introduced in the lecture on one day, and students studied applications the next day in the studio on LON-CAPA software. HSF had two primary purposes; to model and practice problem solving strategies, show physics principles in different contexts, and to review the application of mathematical physics' techniques to describe physical situations/to provide direct hands-on experiences with electromagnetic phenomena in various situations. The activities provided connections between the abstract mathematical forms of the Maxwell laws of electromagnetism and their exhibitions in physical phenomena.

The studio class contained ten tables for groups of up to three/four students; the chairs had wheels to increase the mobility of the students around the table. Each table (workstation) was equipped with four computers. The computers contained LON-CAPA and were connected to the Internet. One printer in the room was shared by all groups. The room had daily lab demo equipment storage. Also near each table, there was a small whiteboard for chalk-talks among students or between students and instructors. At the front center, there were two mobile lecture tables, two overhead projectors, and two large whiteboards for the instructor. The ceiling had a grid of beams capable of supporting apparatus.

Each studio section of roughly 100 students was staffed by two faculty members, two graduates, and two undergraduate teaching assistants. The purpose of this assistant team was to communicate with students and help them. This cooperation led to communication both in HSF (a certain time of the week) and outside the class. Faculty members or graduate teaching assistants then gave "recitation" for 10-15 minutes that serves to introduce the basic concepts and experimental approaches that the students used to examine that day's material. During the largest portion of each class period (~two hours), students worked in pairs or groups of three/four, with instructors moving around the room, answering and asking questions. Thus, students were exposed to teamwork and active learning, and the multiple learning modalities were used to provide friendly learning environment. The last ten minutes or so of each class period were a wrap-up session in which the instructor reviewed the important concepts and student shared data and summarized their findings.

Results

The results for student performance during the use of LON-CAPA system were reported with the cumulative scores from LON-CAPA problems, LON-CAPA homework, written homework, and exams. The final scores on the studio activities (LON-CAPA problems) typically contribute 20% to the grade. The rest of the marks come from lecture participation (5%), homework (written/LON-CAPA) (15%), mid-term exams "3" (15% each), and the final exam (15%). To pass the class, students should gain a score of at least 60%. Exams were given in the traditional method (pen-paper, multiple-choice, and open-ended questions).

Table 1 represents the scores of students` enrolled for F08 and S09 from four different activities. The table clearly shows that students had poorest performance on their exams. The main reason for this outcome could have been students` tight schedules and inability to complete the activities during the semester. Being tested in two hours with 20 problems put much pressure on them during the exams. Exams cover a large variety of chapters and their activities therefore; students couldn't combine and present their knowledge easily.

Also some students had some behaviors which were potential causes of failure. One of these attitudes was students` preference to review the instructor's lecture notes even though the fundamental concepts and exercises were also presented in the textbook. Further, some didn't read the material to be covered in class, didn't come prepared for class and didn't take good lecture notes. They didn't use office contact hours of teaching assistants and instructors to have better understanding of the subject.

Some LON-CAPA activity habits of students may also have caused a decrease in exam scores. These habits can be listed as follows: *i)* there was no feedback to the students that they have completed the problem properly as in LON-CAPA *ii)* students normally focused on getting some answer or calculating some number rather than organizing a problem solving framework on paper *iii)* the interaction they had with their peers in the form of small groups led to their getting lost in the problem as an individual, and students` motivation decreased.

Table 1: Results of the HSF activities in terms of students' grades

	N	LON-CAPA Problems	LON-CAPA Homework	Written Homework	Exams
F08	371	83.40	93.35	82.27	68.40
S09	302	84.74	94.21	76.00	70.24

Note. *The grades weren't considered for students who didn't attend the activities, and the number of students is shown with N.

As remarked in Table 1, another striking result was students` considerably lower grades on manually graded (written) assignments than for LON-CAPA homework. LON-CAPA scores may reflect higher performance because the system has some advantages over written homework. Although they have the ability to enter a solution multiple times with a trial-and-error strategy in LON-CAPA homework, in written homework students have to show their work on the paper and get one correct result. Persistent students can get the correct answer. In addition, the most active member of the group may solve the problem on LON-CAPA and the others get the same grades from that person's effort, while in written assignments he/she has to submit the solution individually. Also, they don't revise and complete the written homework shortly after class while the material is fresh in their mind, thus they forget how to solve that type of problem. Even though it has little effect on the grades, the grading criteria of graduate students who grade the written homework may also change from time to time.

Table 2: Syllabus of Introductory Calculus-Based Physics-II (ICBP-II)

Topic	BLOCK I Electrostatics	BLOCK II Circuits	BLOCK III Magnetics	BLOCK IV Optics
Block 0	Preliminaries; Electrical Properties of Matter	N/A	N/A	N/A
Topic A	Coulomb's Law for Discrete Charges	Capacitance	Magnetic Field Integration-Biot-Savart Law	EM Waves
Topic B	Coulomb's Law for Continuous Charge Distributions	Capacitance II	Magnetic Field-Ampere's Law	Antennae
Topic C	Gauss's Law	Current and Resistance	Magnetic Field and Magnetic Force	Ray Optics

Topic D	Gauss's Law II	Current and Resistance II	Magnetic Force II	Interference I
Topic E	Electric Potential	RC Circuits	Faraday's Law	Interference II
Topic F	Electric Potential II	AC Circuits	Faraday's Law II	Interference III
Topic G	N/A	N/A	Inductance and RL Circuits	N/A

Table 1 shows the distribution of the students` scores for two semesters. The scores on LON-CAPA homework have a strong consistency for two semesters within 5%. The variation in the grades could arise from the difference in the academic background of the students enrolled for that semester. The scores of LON-CAPA problems and exam vary within 10%. The histogram in Figure 6 shows the average scores on the exams taken at the end of each chapter (blocks) in % as a function of two semesters. Detailed chapter content was given in Table 2. The best performance was observed in Block II exams because in this block, circuits were covered and students could connect the theoretical concepts with their daily lives easily (the lights of the Christmas tree). The reasons of the decrease in achievement for Block IV could be related to the decline of the students` attention toward the end of the semester and the increased difficulty of the subject matter.

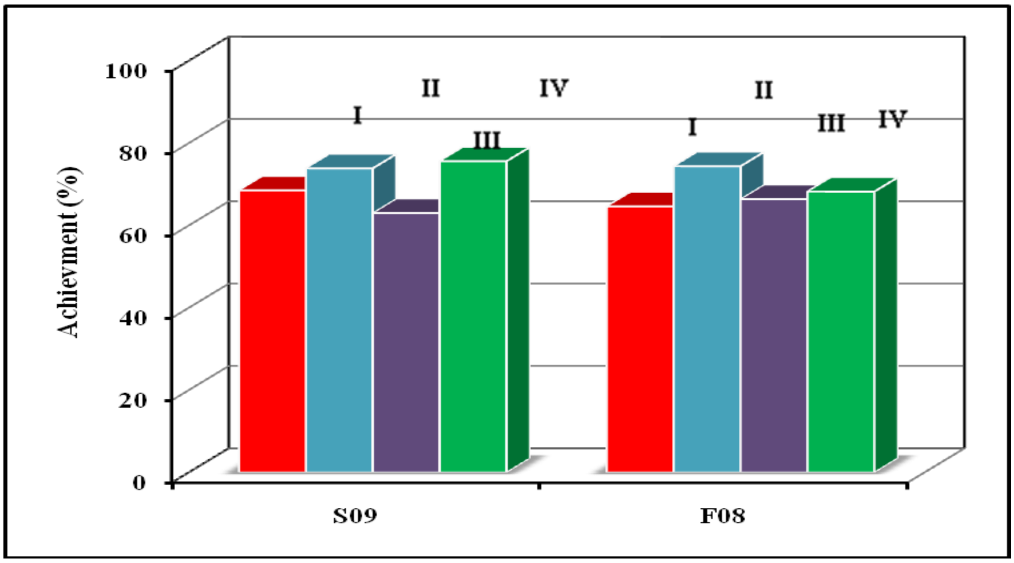

Figure 6: Students` achievement in the exams of Block I-IV

Although students could solve LON-CAPA problems and homework successfully, it was observed that there was a problem getting students to engage with fundamental physics principles and analyze physics situations on pen-paper based assignments/examinations. The problems in LON-CAPA include a lack of detailed solution steps and the danger of multiple tries for gaining results encourages lazy habits of students. Also, corrective hints shift the focus away from the goal to task completion. In that case, students don't spend time to understand the concept behind the problem and continue to adopt formulaic approaches to problem solving. They tend to solve plug-and-chug (single formula problems) or "just like the example" problems rather than complex problems with well-presented solution steps. This does not mean that equations are not important or useful. It means that equations are needed only at the end of the problem solving process, when principles, laws and definitions are applied. The question is: How to get students actively intellectually involved in thinking about the fundamental ideas? We know that fundamental ideas are not easily absorbed by students. But we can adapt their minds to think in an organized way while they are solving a complex problem. This can be possible by incorporating the problem in developed Integrated Problem Solving Strategy steps (IPSS).

General and specific problem solving strategies were examined, to solve this drawback. The most notably general strategies were Dewey's (1910), Polya's (1957), Reif et al., (1976), Reif (1995), and Heller and Heller (1995) problem solving strategy steps. In this study, author presented the selected and modified three steps problem solving strategy based on the problem solving strategies reported by the researchers mentioned before. The developed IPSS (Integrated Problem Solving Strategy Steps) could be summarized as follows:

I. Identifying the Fundamental Principle(s): In the first and most important step, a student should accurately identify and understand the problem. A student should examine both the qualitative and quantitative aspects of the problem and interpret the problem in light of his/her own knowledge and experience. This enables a student to decide whether information is important and what information may be needed. In this step students must: (i) simplify the problem situation by describing it with a diagram or a sketch in terms of simple physical objects and essential physical quantities; (ii) restate what you want to find by naming specific mathematical quantities; (iii) represent the problem with formal concepts and principles.

II. Solving: A student uses qualitative understanding of the problem to prepare a quantitative solution. Dividing the problem into subproblems is an effective strategy for constructing the solution. Thus, the solution process involves repeated applications of the following two steps: (i) choosing some useful subproblems, (ii) carrying out the solution of these subproblems. These steps can then be recursively repeated until the original problem has been solved. The decisions needed to solve a problem arise from choosing subproblems. The two main obstacles can be: (i) lack of needed information, (ii) available numerical relationships which are potentially useful, but contain undesirable features. These choices are promoted if there are only few reasonable options among which a student needs to choose. An effective organization of knowledge has crucial importance in making easy the decisions needed for problem solving. The organization done after applying the particular principle is facilitated by all of a student's previously gained technical knowledge. The final step contains plugging in all the relative quantities into the algebraic solution to determine a numerical value for the wanted unknown quantity.

III. Checking: In the final step, a student should check the solution to assess whether it is correct and satisfactory and to revise it properly if any shortages are detected by following this checklist; (i) Has all wanted information been found? (ii)Are answers expressed in terms of known quantities? (iii)Are units, signs or directions in equations consistent? (iv) Are both magnitudes and directions of vectors specified? (v) Are answers consistent with special cases or with expected functional dependence? (vi) Are answers consistent with those obtained by another solution method? (vii) Are answers and solution as clear and simple as possible? (viii) Are answers in general algebraic form?

The comparison of a problem solved on current LON-CAPA homework problem with pen-based homework problem was given Appendix A and B. As seen given example, while result of problem was only important for LON-CAPA problem, result and solving process of problem were important for pen-based problem. Integrated Problem Solving Strategy Steps are expected to eliminate the potential drawback of LON-CAPA problems/homework and make all students experienced problem solvers both in pen-paper and computer-based problems. In the Appendix C, a sample problem is presented with these Integrated Problem Solving Strategies steps (IPSS) as screenshots. In the *first* screen, students are asked to understand and choose related fundamental concept(s). The s*econd* display leads to the students` selecting the correct diagram or sketch to make the concept clear and then to restate the specific mathematical quantities. In the *third* window students are expected to fill the equation blanks by selecting parameters from symbolic/mathematical expression boxes and to calculate the numerical quantities with units. The f*ourth* screen encourages students to check the solution steps with the checklist if the entry is correct on the previous screen, and at the bottom of the page they confirm the numerical result. On the last page the students review the instructor's solution key.

Discussion and Conclusion

The purpose of this study was to evaluate the performances of the students who enrolled in an Introductory Calculus-Based Physics II course using an interactive engagement approach. To analyze this study, LON-CAPA students' performances (LON-CAPA problem, LON-CAPA homework, written homework, and exams) were used. The results were showed that current LON-CAPA problems and homework have some drawbacks on the exams and pen-paper based (written) homework scores. It was remarked that computer-based problems are not enough to improve students` fundamental and conceptual understanding and problem solving skills completely. The most important reason is that students focus on getting the correct answer by trial-and-error strategy rather than solving the problem in well-defined steps.

In this study, IPSS (Integrated Problem Solving Steps) were developed and incorporated with a LON-CAPA sample problem to encourage students to think in an organized way even when they solve complex problems. Using the IPSS method the number of tries for correct answers may be eliminated to focus the students` attention on getting the correct answer with the "full solution". If developed problem solving strategy steps (IPSS) can be introduced into LON-CAPA problems, it is expected that students will become experienced problem solvers. IPSS also may be used with other on-line homework software (Web Assign, WWWAssign, etc.) and adapted for all undergraduate level science and engineering courses because students are also needed to develop critical thinking in problem solving skills. The value of this program may be useful to the students of varying abilities in problem solving from inexperienced problem solver to experienced problem solver. This will encourage them to transfer this skill to real world applications. From these results, author concludes that students must be taught both concepts and problem solving skills clearly if we want students to be proficient at both. IPSS seems to be a means to perform this idea.

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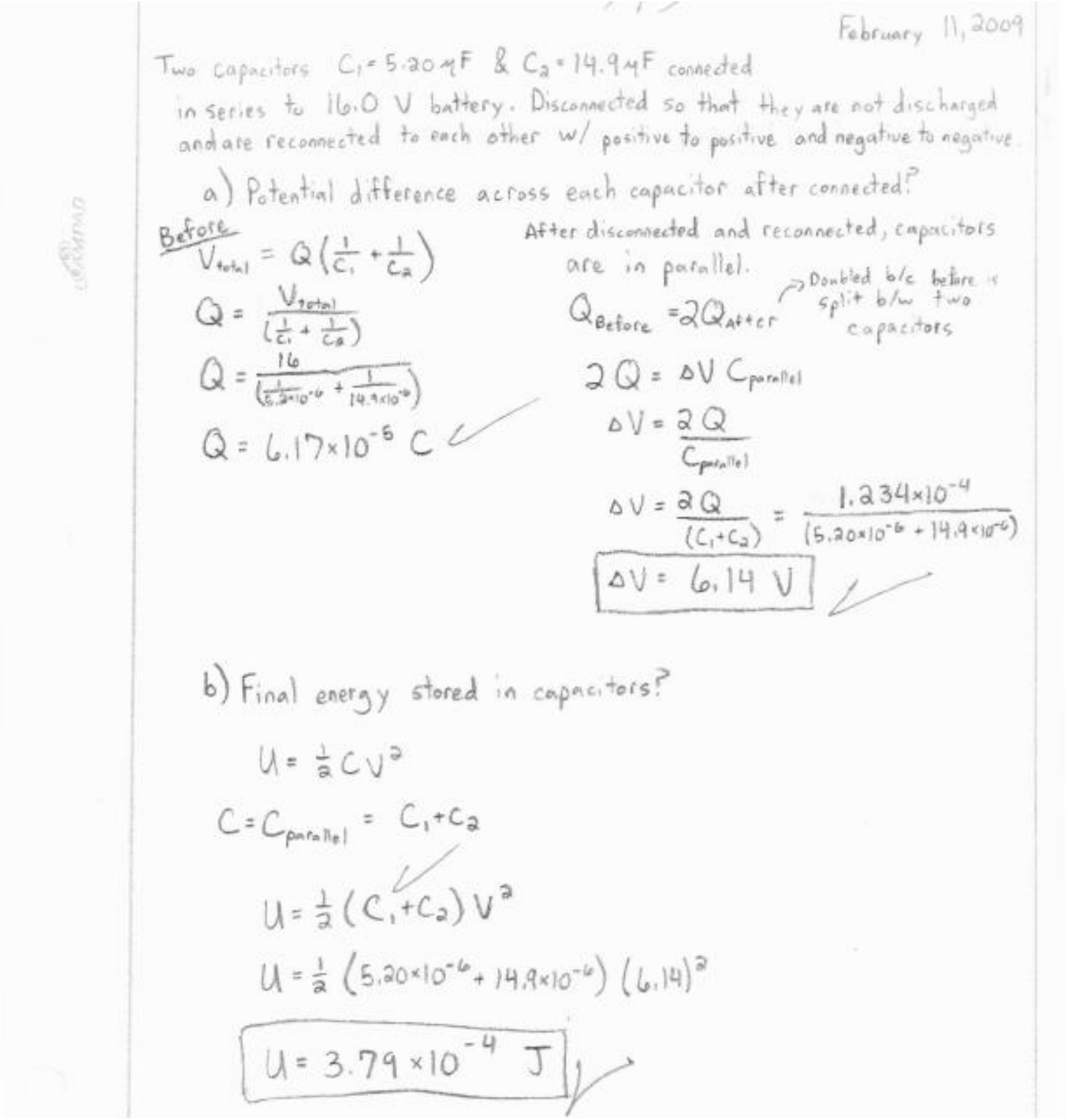
Appendix A: Problem solved on paper by a student



February 11, 2009

Two capacitors $C_1 = 5.20\mu F$ & $C_2 = 14.9\mu F$ connected in series to 16.0 V battery. Disconnected so that they are not discharged and are reconnected to each other w/ positive to positive and negative to negative

a) Potential difference across each capacitor after connected?

Before

$V_{total} = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$

$Q = \frac{V_{total}}{\left(\frac{1}{C_1} + \frac{1}{C_2}\right)}$

$Q = \frac{16}{\left(\frac{1}{5.20\times10^{-6}} + \frac{1}{14.9\times10^{-6}}\right)}$

$Q = 6.17\times10^{-5}$ C

After disconnected and reconnected, capacitors are in parallel.

$Q_{Before} = 2Q_{After}$ → Doubled b/c before is split b/w two capacitors

$2Q = \Delta V\, C_{parallel}$

$\Delta V = \frac{2Q}{C_{parallel}}$

$\Delta V = \frac{2Q}{(C_1 + C_2)} = \frac{1.234\times10^{-4}}{(5.20\times10^{-6} + 14.9\times10^{-6})}$

$\boxed{\Delta V = 6.14 \text{ V}}$

b) Final energy stored in capacitors?

$U = \frac{1}{2}CV^2$

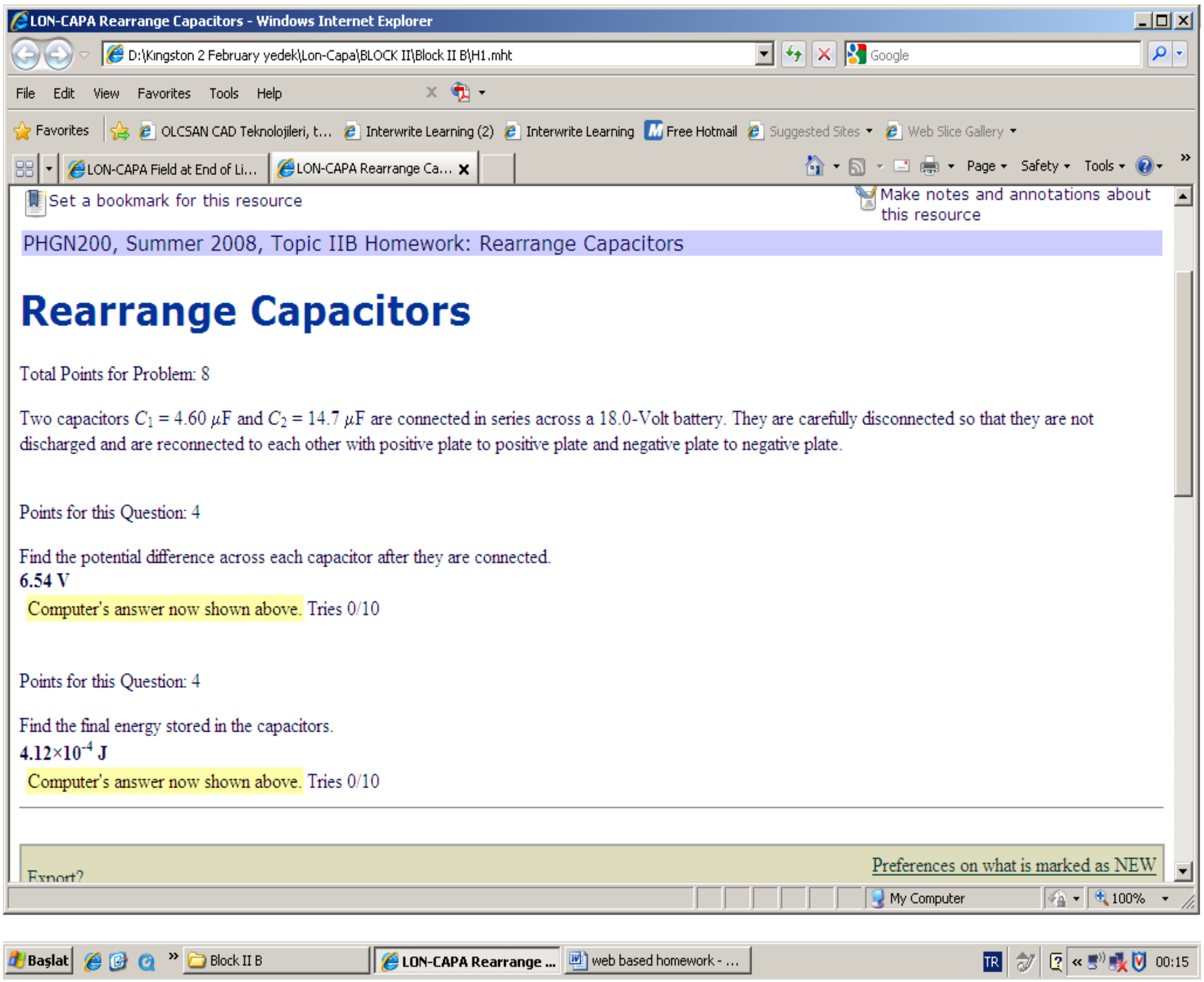
$C = C_{parallel} = C_1 + C_2$

$U = \frac{1}{2}(C_1 + C_2)V^2$

$U = \frac{1}{2}(5.20\times10^{-6} + 14.9\times10^{-6})(6.14)^2$

$\boxed{U = 3.79\times10^{-4} \text{ J}}$

Appendix B: Problem solved on LON-CAPA by a student



Appendix C: Problem solved on LON-CAPA according to IPSS

Problem

Two capacitors $C_1 = 4.60\mu F \text{ and } C_2 = 14.7\mu F$ are connected in series across a 18.0Volt battery. They are carefully disconnected so that they are not discharged and are reconnected to each other with positive plate to positive plate and negative plate to negative plate.

a) Find the potential difference across each capacitor after they are connected.

b) Find the final energy stored in the capacitors.

I

Step 1:Identifying the Fundamental Principles

1. What are the fundamental principles related to given problem?

Click on all correct answers, then click "Done"

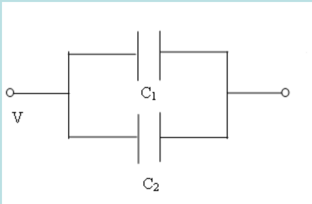
(√) Capacitance	(√) Energy
( ) Gauss's Law	( ) Coulomb's Law
( ) Magnetic Force	( ) Newton's Law
( ) Ohm Law	( ) Power
( ) Ampere's Law	( ) Lenz's Law

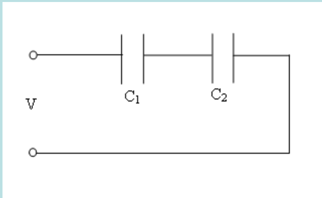
DONE

II

Step 2: Solving (I)

i.) Simplicity the problem situation by describing it with a diagram or a sketch in terms of physical objects and essential physical quantities.

◯ 

(√) 

ii.) Restate what you want to find by naming specific mathematical quantities.

Click on all correct answers, then click "Done"

◯ Magnetic Field	◯ Velocity
◯ Power	◯ Current
(√) Potential	(√) Energy
◯ Current Density	◯ Force

DONE

III

Step 2: Solving (II)

Fundamental Paramaters	Mathematical Calculation Signs
$Q,\ E,\ C_2,\ i$ $j, \Delta V,\ 2Q, 1/2$ $C_1\ \ \Delta V^2, U,\ E_y$	$(-x\vec{i} + y\vec{j}),\ 1,\ \times,\ 0,\ \div,\ \vec{x},$ $\frac{dx}{dy},\ -1,\ +,\ -,\ d\vec{x}\ ,\ \frac{x}{y},$ $(x^2+y^2)^{3/2},\ \sqrt{x^2+y^2},\ (x/y),$ $x\sqrt{y^2+z^2},\ \Big\vert_y^x,\ \int_x^y,\ x_y,\ \sqrt{x}$

I	Potential Difference	__ =__		DONE
II	Final Energy	__= __ __ __		DONE

Note: Equations are expected as shown in reference text book

Result $\Delta V = 6.54V,\quad U = 4.12x10^{-4}\,J$

IV

Step 3: Checking

i) Has all wanted information been found?	√
ii) Are answers expressed in terms of known quantities?	√
iii) Are units, signs or directions in equations consistent?	√
iv) Are both magnitudes and directions of vectors specified?	√
v) Are answers consistent with special cases or with expected functional dependence?	√
vi) Are answers consistent with those obtained by another solution method?	√
vii) Are answers and solution as clear and simple as possible?	√
viii) Are answers in general algebraic form?	√

CONFIRM

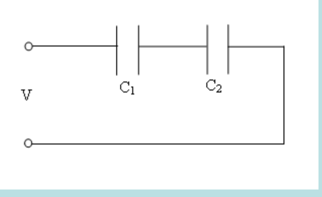
V

Solution of the problem

I. Identifying the Fundamental Principles

I. Capacitance II. Energy

II. Solving



A

Before $Q = C_{eq}V = 63.06\mu C$

After disconnected and reconnected

Capacitors are in parallel

$$\Delta V = \frac{2Q}{C_1 + C_2} = 6.54V$$

B

The final energy stored in the capacitors

$$U = \frac{1}{2}(C_1 + C_2)\Delta V^2 = 4.12x10^{-4} J$$

II. Checking

Unit of the potential	Volt (V)
Unit of the energy	Joule (J)
The results are correct and meaningful	Ok