AC 2007-2972: COMPARING STUDENT EXPERIENCES AND GROWTH IN A COOPERATIVE, HANDS-ON, ACTIVE, PROBLEM BASED LEARNING ENVIRONMENT TO AN ACTIVE, PROBLEM-BASED ENVIRONMENT.

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Abstract

Two questions that frequently come up when developing a teaching method that tries to combine best practices from multiple pedagogies are: Is this better than how we normally teach? And which pedagogy is giving the most benefit. In the spring semester of 2006 we had a large enough junior class to separate our required Fluid Mechanics and Heat Transfer course, ChE 332, into two sections. One section was taught using a novel pedagogy that combines Cooperative, Hands-on, Active, and Problem based learning (CHAPL). The other was taught initially in a manner that attempted to simply remove the hands-on component of the pedagogy. In response to student feedback, this was shifted to an inter-group collaborative environment with each group providing hands-on demonstrations for the rest of the class. As shown by a focus group study, survey, and end-of-semester written course evaluations, the students in the CHAPL section showed greater enthusiasm for the course. Sections of the students reports from projects in the class were also analyzed using a critical thinking rubric (CTR) developed by the Washington State University (WSU) Center for Teaching, Learning, and Technology (CTLT). The CTR assesses four categories (problem identification, solution method, assumption quality and solution quality) on a 6 point scale. The students in the CHAPL section appear to show more growth in critical thinking than those in the other section.

Introduction

Instructors in the science and engineering disciplines are beginning to show enthusiasm for incorporating novel learning pedagogies into their classrooms and are seeing significant results. Some examples of this include POGIL[1], developed in chemistry, and Hi-Pele[2], developed in chemical engineering.

These pedagogies are playing an important role in a Chemical Engineering Fluid Mechanics and Heat Transfer (FMHT) course being taken at Washington State University which employs simultaneous use of *C*ooperative, *H*ands-on, *A*ctive, and *P*roblem based *L*earning or an approach we call CHAPL[3]. The CHAPL pedagogy is a combination of Cooperative, Hands-on, Active, and Problem based learning. Students are divided into home teams. Home teams are instructor assigned to blend students by academic achievement while taking student schedule and preference into account. Each student within a home team is responsible for a core concept of the course. Members of each home team assign the concepts as they see fit. Students from different home teams who have the same core concept form 'jigsaw' groups[4] which spend two class periods developing a teaching module that they will lead their respective home teams through. Each core concept also has a hands-on module that allows for experimentation and illustration. After the jigsaw groups have developed their teaching modules, the home teams rotate through the core concepts. As all of this is going on the professor and TA(s) coach the groups, spending time listening, asking guiding questions, and correcting misconceptions. After this, the home teams have a design project that incorporates all of the concepts covered.

The hands on modules are small scale apparatus mounted on wheeled stands along with a whiteboard. The resulting unit is roughly six feet tall and four feet wide. Even though the modules are largely self contained and require minimal hookups, electricity only for the majority of them, their size relegates them to laboratory space. To address this we developed Desktop Learning Modules (DLMs), the

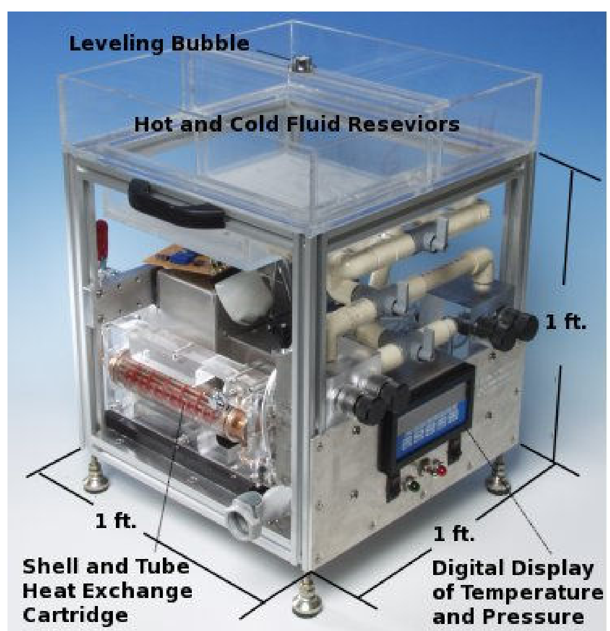

Fig. 1 – DLM design. One gallon reservoirs for hot & cold water feed to interchangeable see-through fluids and heat transfer cartridges with digital display of flow rates, temperatures and pressures.

prototype of which was completed during the spring 2006 semester. The DLM in Figure 1 consists of a 1 ft x 1 ft x 1 ft apparatus containing hot and cold fluid reservoirs, tubing arrangements to direct flows, pitot tubes for determining flow rates, thermocouples and a digital readout screen. In addition the unit was built to receive dollar-sized interchangeable cartridges as shown in Figure 2 including a shell and tube heat exchanger, a double pipe heat exchanger, an extended area heat exchanger constructed from a water cooling unit for temperature control in computer chips, a Reynolds experiment unit with an inclined manometer over a straight section of pipe and an venturi meter, and another flow unit with an orifice meter.

Though the CHAPL results are encouraging, questions remain about just which pedagogy promotes the most benefit, whether the benefits are simply additive or if there are synergies between the pedagogies, or whether at some point the students are overloaded by the introduction of new instructional techniques at it interferes with their learning. We realize that to perform a rigorous study of all combinations of pedagogies and quantify results will take substantial effort over multiple years. However, in this paper we are able to present the initial steps of the process by comparing two sections of our junior level FMHT taught in spring 2006. There were 29 total students in both sections. The comparison includes a full CHAPL section (16 students) to a second section (13 students) taught in a traditional classroom with the first half of the semester focused on using a mixture of lecture and active and problem-based exercises (APL). In the second half of the semester we introduced group centered hands-on learning and a set of demonstrations with a new Desktop Learning Module [5]. Results as will presented in this paper show that students in the full CHAPL section gained more benefit from the course as measured by a critical thinking rubric (CTR) and performance on exams.

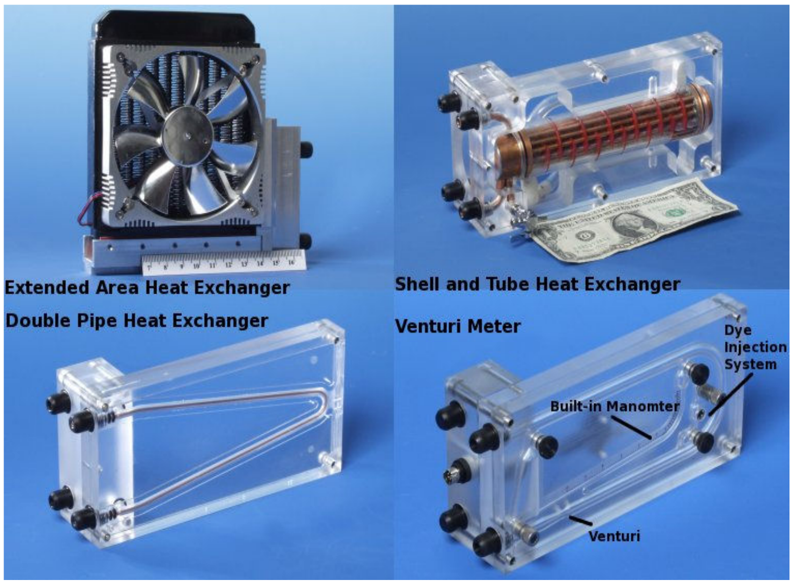

Fig. 2. Four interchangeable DLM cartridges constructed at WSU all of which are on the size order of a dollar bill. The extended area heat exchanger consists of a miniature radiator for a water cooled computer chip along with a standard computer fan. The venturi meter/dye injection unit, and shell & tube and double pipe heat exchangers consist of see-through Plexiglas® so that flow paths and system geometry are readily visible to the students. Cartridge inlets, outlets and electronic interfaces for differential pressure gauges snap into the DLM.

Description of Courses:

Traditional CHAPL Implementation: Our 'traditional' CHAPL implementation is described briefly in the introduction and in detail in a previous publication[3]. This section of the course begins with hands-on modules for understanding the Reynolds experiment, flow in the tube side of a shell and tube heat exchanger and the annular side of a double pipe heat exchanger, pressure drop in a packed and fluidized, bed and flow measurement. The second half of the course adds heat transfer to the heat exchangers and fluidized bed and added hands-on modules for an extended area heat exchanger and a boiler condenser unit.

APL Implementation: In this section of the course we removed the most of the cooperative and hands-on elements leaving an active and problem-based environment. The class was still divided into groups, and class periods typically began with active and problem-based exercises where each group was to think about and discuss a different aspect of a problem, and then report back to the class. For example one might choose a problem where it is desired to pump water from a ground level reservoir to the top of a water tower. One group might be asked to focus on reducing the mechanical energy balance to its proper form for the process, another might be asked to come up with a model for pressure losses due to skin friction, while another might develop the relationships for losses due to fittings, contractions and expansions. After 10 – 15 minutes of discussion the professor would ask each group for input and place the entire system model on the board and continue by adding numerical values and performing the calculation to determine pumping requirements.

During the second half of the semester we introduced the <u>D</u>esktop <u>L</u>earning <u>M</u>odule or DLM [5]. Since we were studying heat transfer in this portion of the class each of three groups took one heat exchanger type and developed a learning module including a reading assignment, take home quiz, a demonstration experiment and fill-in-the blank worksheet for deriving system models and performing calculations. Each group had one class period to present their demonstration experiment display data and lead the class in the fill-in-the-blank exercise. This latter exercise is again problem based, however, since the problem is larger than any one person can handle it may also be described as collaborative learning where each person in a group would focus on development and leading a different aspect of the learning module. This was not truly cooperative learning in that there was no structured positive interdependence and individual accountability within the groups.

Assessments & Results

Focus Groups: At the end of the semester, representatives from Washington State University's Center for Teaching Learning and Technology met with each section and discussed how the course went. Attendance at each session was high, perhaps aided by the offer of coffee and doughnuts. The students were led in discussion of several areas: general attitude, preparation for class, understanding the content, whether the style of the course was hard, positive features of the course, group work, discussions, development of professional skills, and suggestions. The differences were striking and clear. In the full CHAPL course 80% of the students felt they had learned the material compared to 50% of the active, problem-based group. Similarly, 60% of student in the full CHAPL course felt the skills they gained applied to an engineering career compared to 15% in the second group. The latter group reported they felt lost, rushed, and unprepared whereas the student in the full CHAPL section rose to the challenge. *"We weren't prepared at first, but that was the point."* Those in the full CHAPL section were confident in their knowledge and stated they were able to integrate knowledge from multiple sources. Meanwhile those in the active, problem-based section stated they were confused, unable to integrate knowledge from multiple sources, and blamed the textbook for errors, in spite of using the same text as the other section.

Although students in the full CHAPL implementation felt that the class was more challenging than their typical courses, they felt that they had learned more. *"It was a lot more work, but I learned more than in a class where I'd fall asleep taking notes." "I got more conceptual understanding by doing hands-on things." "We had to teach other students about our modules. You had to understand or you'd look stupid. Having to teach it ourselves helped."* Students in the other section were confused, especially when trying to rely on other confused students. They ended up turning to old tests and homework keys for quick solutions after feeling like they had exhausted all other resources.

Although we made an attempt to create groups in such a way that the students in each group had compatible schedules, students in both sections said they resorted to a "divide and conquer" approach due to time constraints. During class time, students in the full CHAPL section felt that discussions were extremely useful and one of their best learning experiences, whereas the other class felt like *"the blind leading the blind."* As for whether this prepared the students for an engineering career, in the full implementation, students felt well prepared because "*employers don't want to hold your hand.*" In the other section, students felt that engineering jobs would allow groups more time to explore and solve problems.

Survey: The students from both sections were also given a survey at the same time as the focus group discussion. Interestingly, in spite of the overall negative tone of the active, problem-based section during the discussion, they reported on the survey one very satisfied, seven satisfied, three unsatisfied, and only one very unsatisfied student, yielding a 61.5% majority positive opinion. The full CHAPL implementation, on the other hand, reported 4 very satisfied, 6 satisfied, 2 unsatisfied and none very unsatisfied for an 83% positive opinion. In both classes most of the students felt that:

- the assignments helped with their ability to work with a team on a large scale project
- the course increased their information literacy skills
- they discussed topics from this class more often than for other courses
- they spent more time on task for this course than for others
- they learned in new ways more in this course than in others
- the course pushed them to think
- they were encouraged to answer their own questions
- they felt comfortable expressing disagreement to the instructor
- course content was relative to their academic interests.

Students in the full CHAPL implementation reported feeling less isolated than students in the other section. Students in the active, problem-based implementation reported a lower perceived development and importance of teamworking and social skills. Most of the students in the modified section also reported that the course design hindered their achievement of learning goals. In contrast over half of the full CHAPL section reported that the course design did not hinder them in their learning goals.

Critical Thinking Rubric: A rubric for assessment of critical thinking was developed especially for this course with a *six-point* scale from novice to expert with four separate categories in which we want to observe critical thinking:

1) How well student identifies and understands the problem;
2) How well student identifies and presents the methods important to the solution;
3) How well student Identifies and assesses the key assumptions;
4) How well student assesses the quality of the solution.

At three points during the course, we assessed a sample of writing from student groups with the intent of determining the level of critical thinking displayed in the writing. The initial assignment given at the first day of class was to write about a homework problem, based largely on the prerequisite course, transport phenomena. The remaining two writings consisted of an 'implications' section added to reports for a design projects completed at the end of each half of the semester. In the active, problem-based section, one student did the first assignment individually rather than as a group, this particular paper is recorded as Group Number 1 in the APL section. Two of the midpoint writings were misplaced and thus not rated. Table 1 reports the average team score for the initial, midpoint and final writings. As can be seen the active, problem-based section showed a

Table 1: Critical Thinking Rubric Results with 90% confidence intervals

	Group Number	**1**	**2**	**3**	**4**	**Average**
APL Results	Initial	3.1±0.6	2.4±0.6	3.1±0.7	2.8±0.8	2.8±0.3
	Midpoint			2.7±0.8	2.2±0.4	2.4±0.8
	Change			-14%	-22%	-13%
	Final		2.1±0.6	2.5±0.4	2.5±0.5	2.4±0.2
	Change			-9%	14%	-3%
	Overall Change		-13%	-21%	-11%	-15%
Full CHAPL Results	Initial	2.3±0.9	2.8±0.7	2.9±0.6	2.7±0.6	2.7±0.2
	Midpoint	2.7±0.5	2.9±0.4	2.3±0.6		2.6±0.3
	Change	18%	2%	-20%		-1%
	Final	2.9±0.5	2.6±0.6	2.8±0.4	2.8±0.5	2.8±0.1
	Change	9%	-9%	19%		5%
	Overall Change	29%	-7%	-4%	2%	4%

net decrease in critical thinking performance ranging from -11 to -21% and an average of -15%. This could be attributed to discouragement, lack of motivation and breakdown of team camaraderie as indicated by abundant and stronger negative statements relating to cooperation among team members – there was after all, by design, less teaching of concepts to each other in this section. By contrast the full CHAPL section showed an overall average increase of 4% in critical thinking with scores ranging from -7 to + 29%. Two of the four groups in the CHAPL section showed decreases, -4 and -7%, but these decreases were on average less than half of the decrease reported for the active, problem-based section. At the same time one group showed a slight increase (2%) with another showing a dramatic increase (29%). This is probably attributable to the increased level of 'buy-in' and motivation shown in the comments from the students in the CHAPL section. However, none of the changes in either section exceeded the confidence interval and are not likely to be significant.

Course Evaluations: The College of Engineering and Architecture at WSU recently switched to an online course evaluation system, so responses to the end of semester course evaluations have dropped somewhat from roughly 70% to 50%. This is reflected in our numbers as well with 8 out of 16 students from the full CHAPL implementation responding, and 10 out of 13 students from the modified section responding. The evaluation consists of a series of multiple choice questions concerning the overall quality of the instruction, homework and tests, followed by two open ended questions asking for suggestions and an overall opinion. There were only four responses to each open ended question from the modified implementation section. In previous years we have used the open ended responses as a feedback mechanism. However, with the low response rate in this semester, these responses were not used.

Class Make-up: As a learning exercise, we require the students to take the Felder-Silverman Learning Styles Inventory[6] early in the semester. We have been tracking these results for four years now. The two sections were essentially identical on the active-reflective, sensing-intuitive, and visual-verbal axis, however they were very different on the sequential-global axis. In the full CHAPL section 75% of the students were sequential learners, compared with 40% in the modified CHAPL section. With the exception of the predomination of global learners in the modified CHAPL section, all of the previous years have followed similar learning style trends to what was seen this semester.

In terms of GPA entering spring 2006 semester, see Figure 3 below, the active, problem based section had, overall, a very slightly larger percentage of the 'best' students in the department (53% of the students with a 3.0 or greater GPA). The full CHAPL section, while having a very slightly larger percentage of the top students (58% of the students with at least a 3.5 GPA), also had slightly more of the bottom students in the department (66% of the 2 – 2.5 GPA range).

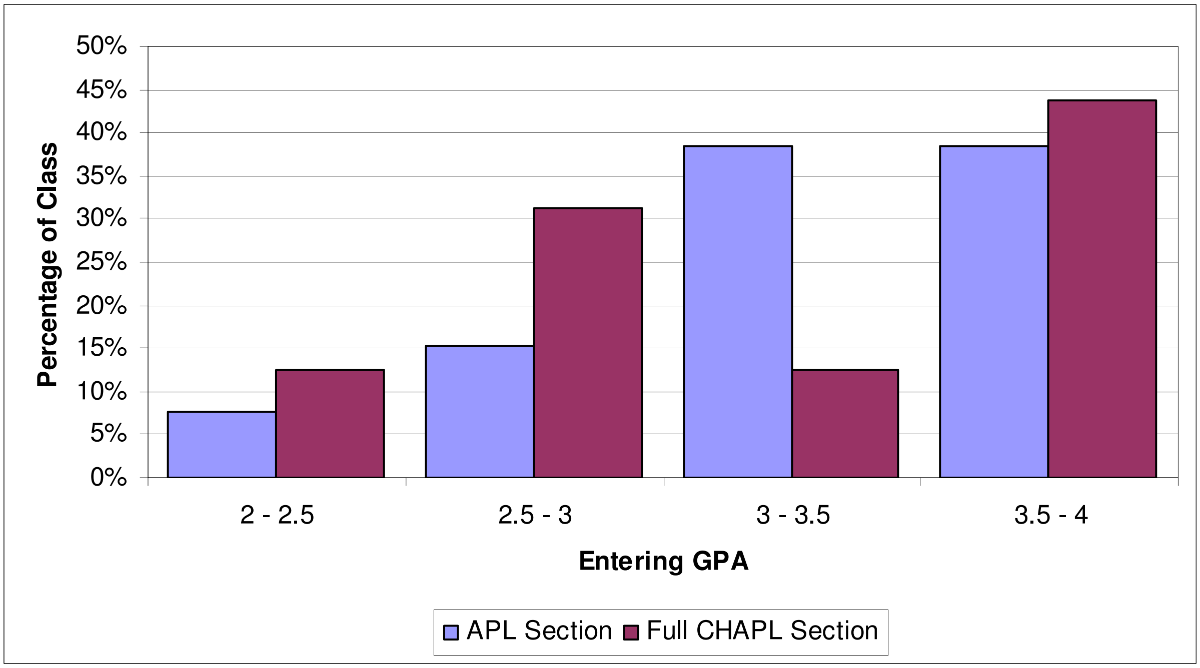

Fig. 3: GPA of students entering the Spring 2006 semester.

Exam Performance: Since both sections were given identical exams, and had equal access to prior years exams as preparatory material, it is useful to compare performance between the two sections. As Figure 4 shows, the full CHAPL section outperformed the active, problem-based section on the first exam, having 66% of the 90-100% scores. Figure 5 illustrates that, across the board, students did not do as well on the second exam, having no scores at all in the 90-100% range and having an overall average of 59% rather than 86%. However, the full CHAPL implementation still outperformed the active, problem-based implementation, having 75% of the top scores in the course.

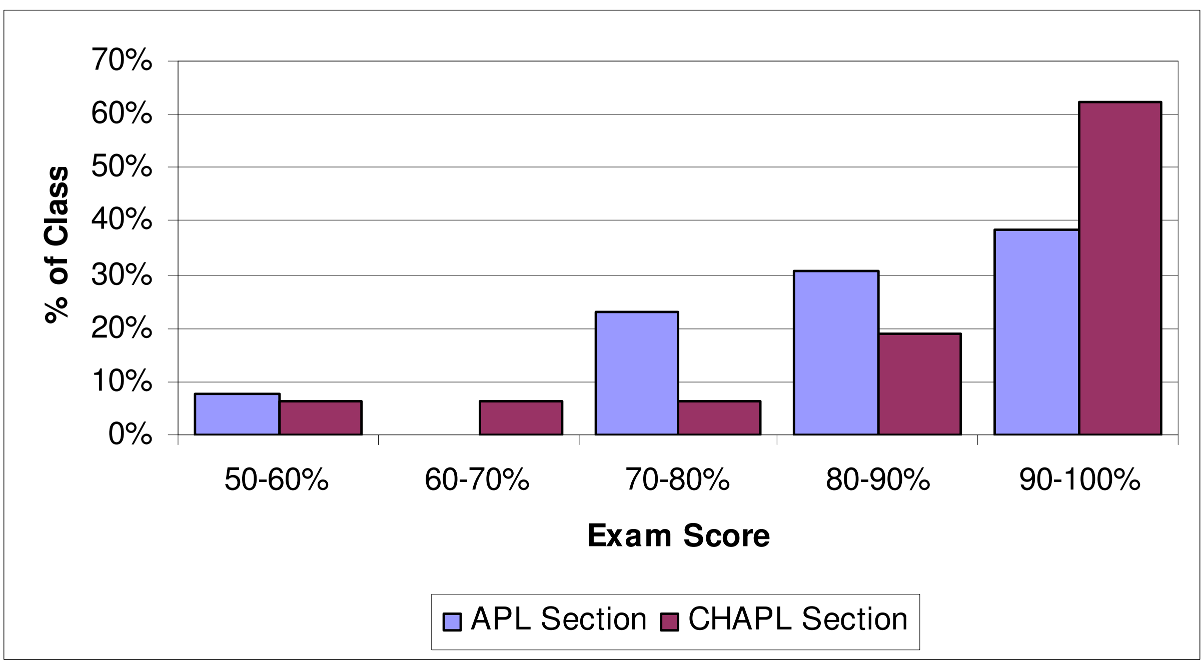

Fig. 4: Performance on the first exam.

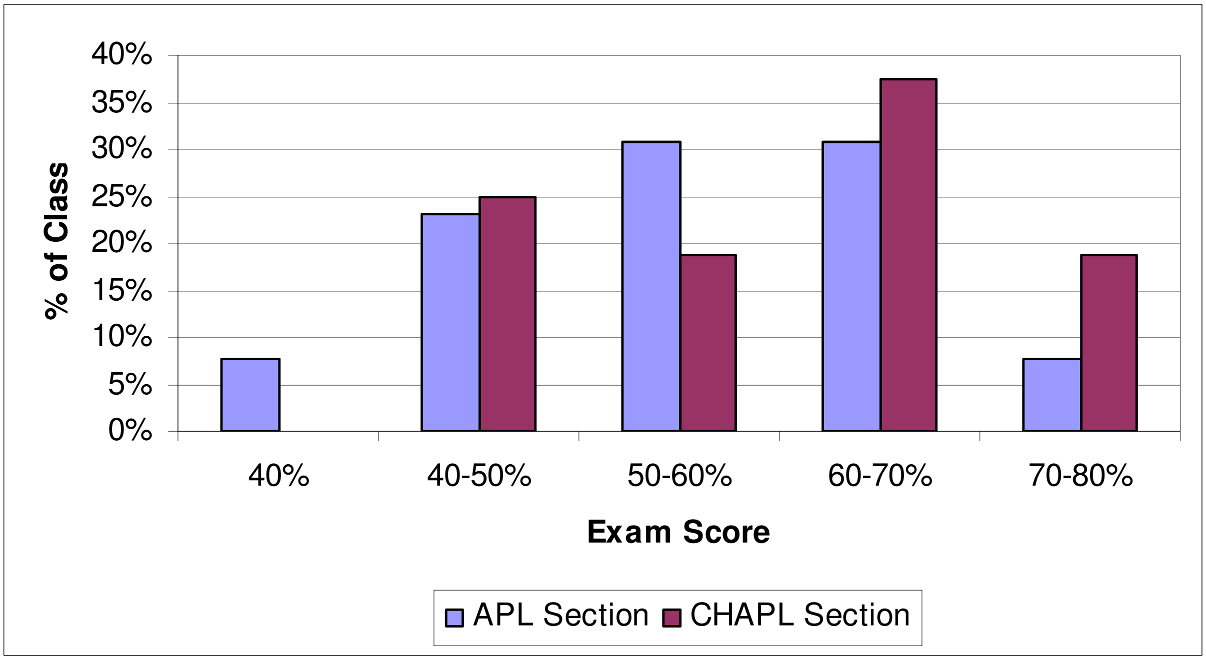

Fig. 5: Performance on the second exam.

Conclusion

We learned that, while a greater hands-on component would have been advantageous in the modified CHAPL implementation, the greatest drawback to this section was the lack of a true cooperative environment. During the second half of the semester, both sections had a hands-on component; therefore the most significant difference during this phase of the course was the cooperative learning element. It is our belief that the problems experienced by the students in this section were a direct result of implementing a problem-based, student taught environment without a strong cooperative learning environment. This probably contributed to the negative comments from the APL section and the lack of trust in the abilities of their group members.

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