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Full Length Research Paper

An examination of hybrid studio set-up applied in preparatory calculus-based physics

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The purpose of this study is to ascertain the performances and perceptions of the students in Hybrid Studio Format (HSF). This format retains the large lecture component but combines recitation and laboratory instruction into Studio Physics. In this research, 'problem solving strategy' and 'attitudes toward problem solving surveys' were administered by pre/post-test to evaluate students' problem solving strategies and attitudes in problem solving. The data on student performance and conceptual understanding was collected by comparing the grades of the students enrolled in Physics course for two semesters (Fall 2008/Spring 2009). Written survey and Likert scales about HSF and LON-CAPA (learningonline network-computer-assisted personalized approach) were used to collect students' opinions about the course. Also multiple interviews were performed with volunteer students about HSF during two semesters. The results of the performance data showed that students performed better on LON-CAPA problems and hands-on activities than on written assignments and exams. The outcome could be some technical features of LON-CAPA which could be easily modified. Open-ended questions, applets and demonstrations were recommended in the studio activities to increase the students' problem solving skills with better conceptual understanding. Student interviews showed that the students found the interactive-engagement method of learning physics to be a positive experience. They liked the integration of homework and laboratory activities, working in groups and having the opportunity to interact individually with instructors. In short, the teaching-learning method presented here, HSF had made a positive impact on the problem-solving skills of students and opinions about the Physics course.

Key words: Hybrid studio format, learningonline network-computer-assisted personalized approach, studio physics.

INTRODUCTION

In recent years, educators have realized and reported that traditionally taught courses were not able to improve students' understanding of the fundamental concepts even if students could solve topic-related problems (Hake, 1998). Besides, in large-scale classrooms (as many as 600 per semester), group activities become harder due to logistical concerns. Students get lost in the crowd and considerable care cannot be taken individually. Also 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 (Hunter, 2000). Research on learning and curriculum development has resulted in instructional materials and teaching methods that can correct many of the drawbacks of traditional physics instruction (McDermott, 1991; Redish and Steinberg, 1999; Van Heuvelen, 1991). It is now known that students learn more physics in classes where they collaborate with peers on interesting tasks and are actively involved with the material they are learning (Mazur, 1997). A computer-based learning support system is one of the realistic ways to meet these demands. Rensselaer Polytechnic Institute "RPI" has introduced a new model for the large enrollment undergraduate courses that has become known as the Studio Model (Wilson, 1994; Young, 1996). The Studio Physics and Studio Calculus were the first created and the model has since been adapted to various courses in chemistry, biology, introduction to engineering analysis, electrical engineering, computer engineering, economics, information technology and computer science.

The studio model is based on a learning environment which was designed to facilitate students` ability to interact with one another, with the instructor and with the course material during their time in class (Wilson, 1994). Studio courses have been introduced to replace some of the large introductory lecture-based courses in science and engineering with a format including daily lectures, in-class activities, homework assignments, hands-on activities which are more integrated and incorporate technology (Wilson and Jennings, 2000). In the studio concept, computers and developed software are used to reinforce the interactive learning with tutorials and simulations for the lecture courses. In addition to that, computers are integrated into the experiments for data gaining and analysis in laboratories. Individualized assignments for both lecture and hands-on activities can be created by computer programs. There are many web-based educational tools available today that can be used in various ways. Some assist in the management of traditional lecture courses, supplement the presentation of some of the material (for example, Authorware-Based Visualization), provide question management and test construction (for example, Question Mark Designer), or enable instructor-student conferencing online (for example, Alta Vista Forum). Other tools (WebCT, WebAssign, etc.) enable entire web-based courses for either local or distance learning. LON-CAPA (learningonline network-computer-assisted personalized approach) software was developed for use in studio classes (Kashy et al., 1993). LON-CAPA is the combination of a course management system, an individualized assessment system, and a learning resources management system. This system is a specialized single component rather than a complete web-based program. It can be used in conjunction with other web-based tools such as conferencing utilities or material presentation modules to provide an entirely online program or it can be used in conjunction with lectures and recitations in a more traditional course.

LON-CAPA, while similar to many others (WebCT, WebAssign, WWWAssign, etc.) in most aspects differs in three important ways. 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. The second is assisting 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 goal of the internet. 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. 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 online homework, can also create them for an online examination, or for a printed version suitable for an examination sheet examination which is later machine scored (Kortemeyer et al., 2005). LON-CAPA, a free open source software, was originally developed at Michigan State University, and has its roots in the earlier software systems LON-CAPA (Kashy et al., 1995), multimedia physics (Bauer et al., 1992) and LectureOnline (Kortemeyer and Bauer, 1999). LON-CAPA has been used in many classes of physics, chemistry, calculus, biology, mathematics, psychology, statistics, and several other subjects (Kashy et al., 1995; Kortemeyer et al., 2008). The system provides a large variety of conceptual and quantitative problem functionality for personalized assignments, quizzes, and examinations (Kashy et al., 1993, 2001; Kortemeyer et al., 2008; Kortemeyer, 2009; Morrissey et al., 1995).

The sophisticated LON-CAPA includes three parts: 1) Quizzer: to create questions and prepare personalized problem sets or examinations, 2) Grader: to record student responses and scores, 3) Manager: to create class reports and compile various statistical information which is available with a detailed description of LON-CAPA (Hunter, 2000). Previous studies on studio and 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 presents detailed investigation on hybrid studio format (HSF) with students' performances, opinions, and problem solving skills in Introductory Calculus Based-Physics. The perceptions and problem solving skills of the students taught by HSF have not been elucidated in

Table 1. Syllabus of Introductory Calculus-Based Physics II (ICBP-II).

Topic	Block I electrostatics	Block II circuits	Block III magnetics	Block IV optics
Preliminary	**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

the open literature as of 2010.

MATERIALS AND METHODS

The investigation was conducted with hybrid studio format “HSF” (lecture/studio physics/LON-CAPA) in the Introductory Calculus-Based Physics II (ICBP-II) for two semesters (Fall 2008 to Spring 2009). 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. Each semester, the students were divided into three class sections were taught by two instructors that followed the same syllabus (Table 1), 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 Studio Physics (a certain time of the week) and outside the class. Faculty members or graduate teaching assistants then gave “recitation” for 10 to 15 min 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 (~2 h), 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. The data were collected with grades of students taken from LON-CAPA problems (LON-CAPA, 2008) (asked on computer in studio), LON-CAPA homework (assign to be submitted online after studio in a week), written homework (assign to be submitted in paper format in a week), hands-on activities (lab experiments performed in studio) and exams (given four times in a semester, three mid-terms and one final). The performances of students during two semesters were discussed technically and pedagogically. Problem solving strategies survey (PSSS) and attitudes toward problem solving survey (APSS) were given to monitor students’ problem solving strategies used and their attitudes in problem solving process. Written survey and Likert scales about HSF and LON-CAPA were used to collect students’ opinions about the course. Also multiple interviews were performed with volunteer students during two semesters. Those data collecting tools assisted to probe the following research questions:

1) Does HSF change the problem solving strategies of

students?

2) Does HSF change the students' attitudes toward problem solving?

3) How is the students' performance in HSF? Which activity makes the most impact on average scores? Are scores obtained from two semesters consistent?

4) Do students find HSF as a positive learning experience?

Development of problem solving strategies survey (PSSS) and attitudes toward problem solving survey (APSS)

The primary purpose was to monitor the strategies that students use and their attitudes, opinions in problem solving process including LON-CAPA. The strategies and attitudes were defined with two different surveys problem solving strategies survey (PSSS) and attitudes toward problem solving survey (APSS). Surveys were conducted at the beginning (pre-test) and end (post-test) of the F08/S09. Author developed these surveys with the help of 310 student essays on problem solving styles and attitudes in the spring semester of 2008 (S08). The responses were compiled into 40 questions about problem solving strategies and 30 questions about their attitudes. As a result of verification and validation of these surveys with the application for 540 science and engineering students, the survey item numbers were decreased to 25 and 19 items, respectively. All statistical analyses were performed with SPSS (statistical package for the social science) 15.0 software for Windows. Validity of surveys was tested with the varimax rotation and principal component analyses. The items were selected considering the rule anticipating that the item factor load should be over 0.40 as a result of the varimax rotation (Coombs and Schroeder, 1988). The difference between two loads was at least 0.10 when the item takes place at more than one factor (Appendix A). The construct validity of the surveys was obtained by Bartlett's test of sphericity. When correlation between variables was close to one, the factor analysis was considered as appropriate. According to this, the results of Bartlett's test of sphericity were obtained as 12343.77 and 10788.53 for PSSS and APSS, respectively. This test showed that the data used in these surveys did not produce an identity matrix. Thus, multivariate normal distribution was acceptable for applied factor analysis (Dunteman, 1989; Hair et al., 1998). Besides, as a result of the principal component analysis, the values of Kaiser-Meyer-Olkin (KMO>0.60) were found as 0.90 and 0.92 for PSSS and APSS, respectively.

KMO test confirmed with the small partial correlations and sufficient distribution for the factor analysis. KMO values found for these surveys were defined as "very good" (Hutcheson and Sofroniou, 1999). As a result of rotation analyses conducted with the principal component analysis and varimax method, three (PSSS) and two (APSS) subscales were defined. The subscales of PSSS consisted of "identifying the fundamental principle", "solving" and "checking". The APSS had two subscales which were: "positive attitudes" and "negative attitudes". For reliability analysis of the surveys, Cronbach's alpha was used to examine the reliability of the proposed items within each subscale of the surveys. The acceptable level of reliability for two surveys was considered when the Cronbach's alpha values over 0.70 (Santos, 1999). The results of the Cronbach's Alpha values of PSSS and APSS were obtained as 0.86, and 0.85 respectively. Cronbach's Alpha values for each subscale of these surveys were calculated (Hutcheson and Sofroniou, 1999). Further, the eigenvalues for the factors, variance percentages and total variance percentages for PSSS and APSS were obtained. The number of initial factors was found from the eigenvalues which were greater than 1.00 (Pett et al., 2003). These three factors of PSSS explained the total variance by 63.86%. The percentage was 62.36% for APSS. The percentages were accepted as suitable to evaluate with three (PSSS) and two (APSS) factors according to the research of Kline (1994) (>41%). 25 (PSSS) and 19 (APSS) items were selected after the validity analysis with the factor loads over 0.40 (Appendixes A and B).

Written survey, Likert scales for HSF and LON-CAPA, and interview questions

The data collection tools (besides PSSS and APSS) - written survey including six open-ended questions about HSF, Likert scale consisting ten questions about HSF and twelve questions about LON-CAPA, and Interview about HSF in which students asked seven questions- were used in the study for both semesters (F08-S09). The secondary goal of the research was to enhance the format of the Introductory Calculus-Based Physics II course by giving the students a better learning experience, finding out their opinions. A 'written survey' about HSF (Churukan, 2002) was given to the students during their studio time at the end of each semester. The students were informed about why the survey was given and also they were under no obligation to complete it. Some students opted to take the time to study for another class rather than complete the survey. However, generally giving the students the opportunity to tell us what they would change, not only reinforced the sense that we cared about what they think, it also gave us valuable suggestions of what we could improve from the students' belief. The open-ended questions included in the written survey (pp: 6 to 7) reflected what the students liked and disliked about HSF in general and about working in teams in particular. Author also wanted to know what the students would change about HSF. The responses of the students to six questions were grouped and analyzed statistically. HSF-Likert scale (seven items of ten) (Churukan, 2002) probed how well the student felt HSF met criteria such as coordination between lecture, homework and hands-on activity work. The remaining items examined the communication among the students and between the students and instructors. Five-level Likert item format (Table 5) was ordered as "1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree". The scale was given in both semesters (F08-S09) and the responses were analyzed statistically with SPSS software.

LON-CAPA- Likert scale (Hrepic, 2007) addressed the changes in students' feelings, communication skills, motivation levels and cognitive advantages of the system. Four-level Likert item format (Table 6) was ordered as "1-strongly disagree, 2-disagree, 3-agree and 4-strongly agree". The scale was given in both semesters (F08-S09) and the same analysis procedure with the first Likert scale was applied. In the 'interview stage', students were asked to be interviewed voluntarily throughout both semesters (F08-S09) about HSF. The purpose of the interviews was to learn student's approaches to the exam questions, if they use the strategy that they learned in the course and comments to improve the HSF. By the end of the semesters, 125 students were interviewed (554 interviews). Seven open-ended questions (Appendix C) were asked three times during the semester-after each exam except the final. The interviews were usually conducted within a week after the exams were returned to the students. The interviews were conducted in a semi-structured format. A predetermined set of questions was used as a guide, so certain topics would be included in all interviews. At their first interview, the students were informed about the purpose of the interviews and how the interviews fit into the greater scheme of the evaluation process of the change made to the Introductory Calculus-Based Physics II course. They were also reminded that if, at any time they felt uncomfortable with the process they were free to withdraw from the study with no penalty. Students had the opportunity to lead the conversation. They sometimes answered questions before being asked.

Table 2. Mean, standard deviation and Cohen's d values obtained from PSSS.

	Fall 2008 (F08)				Cohen's d	Spring 2009 (S09)				Cohen's d
	Pre-test		Post-test			Pre-test		Post-test		
Subscales	**M**	**SD**	**M**	**SD**		**M**	**SD**	**M**	**SD**	
Identifying the fundamental principle	41.23	2.86	57.72	2.59	6.04	42.02	2.74	58.14	2.58	6.05
Solving	16.54	2.55	22.51	2.47	2.37	16.08	2.62	21.38	2.49	2.07
Checking	14.67	2.45	19.78	2.40	2.10	14.51	2.50	19.83	2.46	2.14
Total	72.44	2.62	100.01	2.48	10.80	72.61	2.59	99.35	2.51	10.48

Note: The number of the students who answered the PSSS for F08 is 120; the number of the students who answered the PSSS for S09 is 100; statistically significant (defined as $p<0.05$) and critical value $t = 2.00$.

Table 3. Mean, standard deviation and Cohen's d values obtained from APSS.

	Fall 2008 (F08)				Cohen's d	Spring 2009 (S09)				Cohen's d
	Pre-test		Post-test			Pre-test		Post-test		
Subscales	**M**	**SD**	**M**	**SD**		**M**	**SD**	**M**	**SD**	
Positive attitudes	18.90	2.85	35.49	2.63	6.02	18.21	3.08	36.82	2.89	6.23
Negative attitudes	34.65	2.80	26.12	2.57	3.17	35.48	2.84	27.37	2.54	3.01
Total	53.55	2.82	61.61	2.54	3.00	53.69	2.98	64.19	2.71	3.68

Note: The number of the students who answered the APSS for F08 is 120; the number of the students who answered the APSS for S09 is 100; statistically significant (defined as $p<0.05$) and critical value $t = 2.00$.

The exams gave a starting point of conversation as well as providing insight into the students' thinking process. The responses of the students were categorized and analyzed statistically with the same procedure used in Likert scales (Tables 7 to 8).

RESULTS AND DISCUSSION

The investigation on hybrid studio format (HSF) applied in Introductory Calculus Based-Physics II course was performed by PSSS, APSS, students' scores of HSF activities and interviews. These data collection tools provided the responses to the following research questions.

RQ 1: Does HSF change the problem solving strategies of students?

Problem solving strategies survey was used to observe the change in problem solving strategies of the 220 students by pre and post test. The statistical analysis assisted to obtain three main strategies that students use. These are "identifying the fundamental principle", "solving" and "checking". The significant statistical difference were found between pre and post test for two semesters. The highest increase (25.37%) was for the first strategy obtained in F08. Results indicate that HSF encourages students to use the problem solving strategies while solving a problem (Table 2). The total increases of strategy use were 22.05% in F08 and 21.04% in S09. Standard deviation was around 2.5 for the analyses. Cohen's d values support this outcome by large effect size "Cohen's d >0.8" (Cohen, 1988).

RQ 2: Does HSF change the students' attitudes toward problem solving?

Attitudes toward 'problem solving survey' were applied to monitor the positive improvements in 220 students' opinion during problem solving process. Statistical analysis (Table 3) indicates the significant difference between pre and post test for two semesters. Values indicates that the positive attitudes increased by 41.47% in F08 and 46.53% in S09. As expected, negative attitudes decreased by 15.51% in F08 and 14.74% in S09. The positive attitudes and negative attitudes are listed in Appendix B. Students' responses show that their opinions and attitudes were facilitated with HSF. Standard deviation was around 3 for the analyses.

Table 4. Students' scores taken from HSF activities.

	N	LON-CAPA problems	Hands-on activities	LON-CAPA homework	Written homework	Exams
Fall 2008	120	83.40	75.87	93.35	82.27	68.40
Spring 2009	100	84.74	80.05	94.21	76.00	70.24

Note. The grades were not considered for students who did not attend the activities and the number of students is shown with N. The number of the students for F08 is 120. The number of the students for S09 is 100.

Cohen's d values confirmed the positive change in students' opinions on solving a problem with large effect.

RQ 3: How is the students' performance in HSF? Which activity makes the most impact on average scores? Are scores obtained from two semesters consistent?

The performances of 220 students during the course (applied with HSF) are reported with the cumulative grades from hands-on activities, LON-CAPA problems, LON-CAPA/written homework, and exams for F08 and S09 in Table 4. Exams were given in the traditional method (pen-paper, multiple-choice, and open-ended questions). The difficulty levels of LON-CAPA problems asked in LON-CAPA homework, written homework, and exams are set as same. Hands-on activities were based on the laboratory experiments and the questions asked in exams related to the experiments were fundamental principle problems which have the same difficulty level with the problems asked in other activities. Table 4 clearly shows that the students have high performance in all activities (Average grade ≥ 60). However, when scores were compared among each other, it is observed that students have lower performance on their exams. The main reason for this outcome could have been students` tight schedules including lecture, studio, and assignment hours. Also, as in all exams being tested in two hours with 20 problems put much pressure on them. Because of the syllabus, exams cover a large variety of chapters and their activities. Some technical features of LON-CAPA could be improved:

Automatic feedback

In current version there is no feedback to the students that they have completed the problem properly as in LON-CAPA.

Decrease the number of attempts

Students normally focus on getting some answer or calculating some number with 99 attempts.

Incorporation of simulations

Students do not visualize the real-world concepts. As remarked in Table 4, another striking result is students` lower grades on manually graded (written) assignments than for LON-CAPA homework. LON-CAPA score reflects higher performance because the system has some advantages over written homework. They have the ability to enter a solution multiple times with a trial-and-error strategy in LON-CAPA homework. Persistent students can get the correct answer. However, in written homework, the students have to show their work on the paper and get one correct result. The most active member of the group often 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 might not revise and complete the written homework shortly after class while the material is fresh in their mind, thus they might forget how to solve that type of problem. Another outcome is that students are more successful in solving chapter problems on computer (LON-CAPA problems) than doing experiments (hands-on activities) in the studio class. The results indicate that students have difficulty in making conceptual connections between physical facts and theoretical problems about same fundamentals. The hands-on activity providing related demonstrations or applets might cater for effective approach to physical representation of fundamental concepts. In the hands-on activities if the instructor or teaching assistants do not give a short talk at the beginning of the lab, students don't have enough understanding of the purpose of the experiment. The problem could also be the students' distractions by computer activities (internet, online games, etc.). The histogram in Figure 1 shows the average scores on the exams taken at the end of each chapter (blocks) in percentage as a function of two semesters. Detailed chapter content is given in Table 1. The best performance is observed in Block II exams in this block, because 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.

Table 5. Likert scale about HSF and analysis for both semesters.

Items	Strongly disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly agree (%)
The connections between the homework and the hands-on activity were always very clear and apparent.	2.4	9.9	23.8	53.3	10.6
The connections between the hands-on activity and lecture were always very clear and apparent.	1.3	1.6	24.3	57.2	9.1
The connections between lecture and homework were always very clear and apparent.	5.4	10.1	24.5	54.2	5.8
I am satisfied with the level of use of computers in studio.	7.0	7.3	24.1	53.8	7.3
I am satisfied with the physical arrangement of the studio classroom.	2.3	10.9	23.2	50.4	13.2
There is more to physics than problem solving.	0.5	12.3	24.9	60.6	1.7
The interaction of problem solving and hands-on activity helped me learn physics.	5.5	4.5	22.6	58.2	9.2
I am satisfied with the amount of interaction I had with the studio instructors.	5.0	5.9	24.8	57.6	6.6
There is strong communication between teaching assistants and teams.	4.3	12.9	24.3	55.1	3.4
There is strong communication between instructors and teams	7.6	14.2	21.2	45.3	11.7

Note: Total number of the students for F08 and S09 is 220.

Table 6. Likert scale about LON-CAPA and analysis for both semesters.

Statement: Using LON-CAPA …	Category	Strongly disagree (%)	Disagree (%)	Agree (%)	Strongly agree (%)
Was enjoyable	Affect	7.9	24	62.6	4.9
Made learning more fun		7.9	22.4	54.6	14.5
Was very challenging		9.6	57.8	28.8	3.2
Was very frustrating		24.1	44.9	16.2	14.5
Was a waste of time		35.3	43.3	11.2	9.6
Helped me take better set of notes “PDF”	Cognition	7.9	11.2	51.3	29
Facilitated my learning		4.8	12.8	56.2	25.6
Enhanced my understanding of the course material		7.9	20.7	54.6	16.2
Enhanced my interaction with team members	Communication	4.9	11.2	56.2	27.2
Enhanced my interaction with the teaching assistant team		7.9	9.6	60.9	21
I was more attentive when LON-CAPA was used	Motivation	6.5	17.6	52.9	22.4
I was more motivated when LON-CAPA was used		14.5	24.1	44.8	16.1

Note: Total number of the students for F08 and S09 is 220.

Table 7. Statistical analysis of interview on the influences, distracters and changes in HSF.

	Question number	Females (%)	Males (%)	Total (%)
Influences	**1a, 1b, 2a, 3a, 4**			
Hybrid studio format		41.88	58.11	93.60
Hands-on activity		40.00	60.00	92.00
Homework		42.72	57.27	88.00
Review sessions		36.98	63.01	58.40
Lectures		37.50	62.50	44.80
Wrap-up/quiz		53.843	64.86	41.60
Distracters	5			
Nothing		40.77	59.22	82.40
Other classes		36.66	63.33	24.00
Too much information too fast		27.58	72.41	23.20
Time management		46.15	53.84	20.80
Team Members		41.66	58.33	19.20
Lack of interest/motivation		40.90	59.09	17.60
Being Tired		36.84	63.15	15.20
Changes	2b, 3b, 4a, 6e			
No Change		40.47	59.29	90.04
Need more class sessions: lecture and/or studio		36.36	63.63	17.60
Exchange the grading scale		45.00	55.00	16.00
Focus more on problem solving and less hands-on activity		52.63	47.36	15.20
Have weekly review/help periods		33.33	66.66	14.40
Need more faculty/assistant helping in studio classroom		23.52	76.47	13.6
Improve the hands-on activity worksheet		43.75	56.25	12.80

Note: The number of the students who were interviewed is 59; “question numbers” presents the questions of the interview (Appendix C).

Table 8. Statistical analysis of interview on the likes, dislikes and collaborative teams in HSF.

	Question number	Females (%)	Males (%)	Total (%)
Likes	**6a, 6b**			
No hands-on activity assignment outside studio classroom		42.50	57.50	96.00
Like in general		42.60	57.39	92.00
Combining homework and hands-on activity		42.85	57.14	89.60
Going over homework		43.51	56.48	86.40
The hands-on activities		45.37	54.62	86.40
Friendly working environment		43.56	56.43	80.80
Exchange the teams		40.35	59.64	45.60
Dislikes	6a, 6d			
Time deficiency for completing assignment		43.83	56.16	58.4
Collaborative teams	6c			
Learning from team members		39.81	60.18	86.40
Some team members not interested in doing the hands-on activities		53.84	46.15	31.20

Note: The number of the students who were interviewed is 59. “Question numbers” presents the questions of the interview

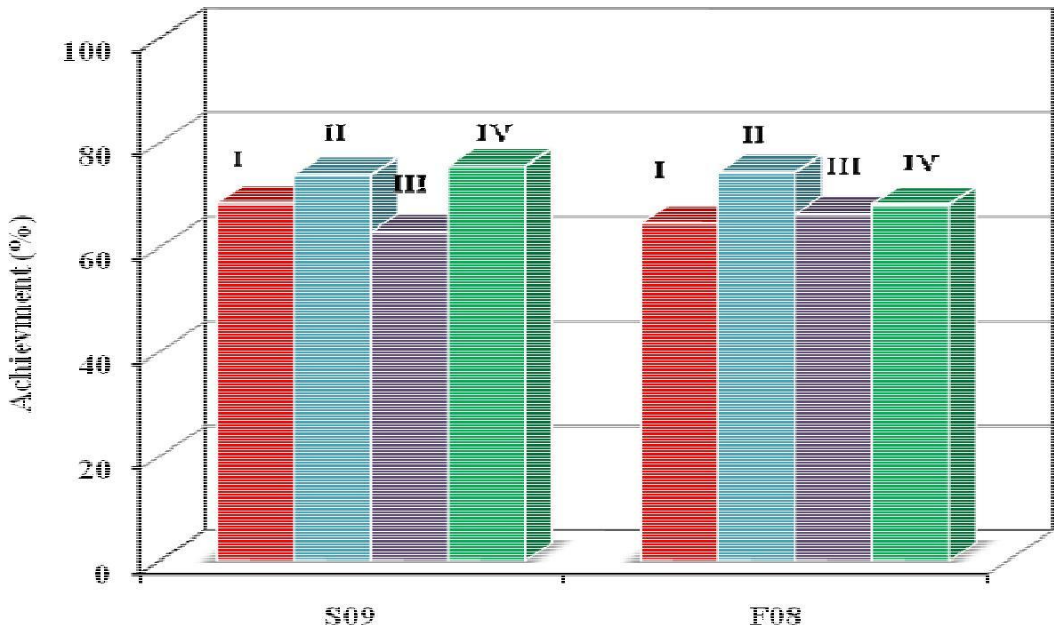

Figure 1. Students` achievement in the exams of Blocks I to IV (I: electrostatics; II: circuits; III: magnetics; IV: optics).

Table 4 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 be caused by the difference in the academic background of the students enrolled for that.

RQ4: Do students find HSF as a positive learning experience?

Open-ended questions

Six open-ended questions were asked to 220 students to learn students' opinions about learning this course with HSF. For each question, author categorized the responses to obtain the general opinion about this teaching/learning method. The questions and most frequent responses are listed as follows:

1) What did you like about 'hybrid studio format'?

a) Hands-on nature of HSF (93% of students).

b) Homework problems solved on LON-CAPA (85% of students).

c) Integration and/or incorporation of the hands-on activities with going over the homework (all students).

d) Collaborative working in small teams (90% of students).

e) Experiments on the concepts discussed in lecture (92% of students).

f) Opportunity for one-on-one interaction with instructors (98% of students).

g) No hands-on activity assignment outside the studio classroom (all students).

h) Friendly working environment (95% of students).

2) What did you dislike about 'hybrid studio format'?

a) Individual studio periods seemed too long from time to time (91% of students).

b) Some of the hands-on activities were pointless, unhelpful and poorly planned (9% of students).

c) The grading was unfair from time to time (12% of students).

d) Being quizzed over material that was not showed (35% of students).

e) Felt rushed to finish hands-on activities and/or homework sessions from time to time (89% of students).

3) What did you like about collaborative working in teams?

a) Everyone brought new ideas and opinions to the workstation (94% of students).

b) Getting to meet new people and make new friends (93% of students).

c) Learning from team members (97% of students).

d) Team members helped when a member had questions (all students).

e) Helped learn cooperation and communication skills

(90% of students).

f) Easier to work out problems and to learn (92% of students).

4) What did you dislike about collaborative working in teams?

a) Unequal effort given by team members (87% of students).

b) Some team members are easier to work with than others (93% of students).

c) Exchange teams after each mid-term exam (76% of students).

5) For next semester, what would you change about 'hybrid studio format'?

a) Allow more time for hands-on activity work or fewer hands-on activities (86% of students).

b) Devote more time to solving homework problems on LON-CAPA (75% of students).

c) Clarify the goals and refine the procedures of the hands-on activities (92% of students).

6) What would you keep the same about the way 'hybrid studio format' is taught?

a) Checking out the homework problems at LON-CAPA (85% of students).

b) Collaborative working in small teams (78% of students).

c) Some hands-on activities are perfect (64% of students).

d) Incorporating homework with the hands-on activities (59% of students).

HSF-Likert scale

Five-Likert scale was given to 220 students and their responses were analyzed. The 67.40% of students agreed on the item of "interaction of problem solving and hands-on activity helped me learn physics". The 21.8% of students disagreed on the item of "there is strong communication between instructors and teams". According to survey results, students felt that connections between the homework, hands-on activity, and lecture parts of the course were clear and obvious. They were satisfied with the amount that computers were used in the studio as well as the physical studio classroom arrangement. In addition, they were satisfied with the amount of interaction they had with the instructors and felt to integrate homework with hands-on activity work helped them learn physics. However, the students pointed out that, as a team, they often interacted with the teaching assistants (TAs) while students less interacted with the course instructors. The instructors did not stay in the studio classroom the entire time and students could not ask their questions about LON-CAPA problems. But this was the main point; encourage them to work cooperatively with their team members. Also there were teaching assistants to give sufficient hints.

LON-CAPA-Likert scale

Four-Likert scale was given to 220 students. The results show that the affects on LON-CAPA are highly favorable. Most students enjoyed using LON-CAPA software (67.5%) although some students (20.8%) thought she/he wasted time using LON-CAPA. At the same time, the level of frustration with LON-CAPA was lower (30.7%) with respect to the level of enjoyment (67.5%), and according to the comments in the follow up questions, this was firstly caused by technical difficulties with the network rather than the software itself. Most students thought LON-CAPA helped them take better lecture notes and save them easily (80.3%), and it facilitated their learning (81.8%). Most believed LON-CAPA improved students' interaction with both the teaching assistant team (81.9%) and their team members (83.4%). Further, 75.3% of students said that they were more attentive when LON-CAPA was used and 60.9% felt more motivated.

Interviews about HSF

Students were asked to be interviewed voluntarily throughout the semesters. The purpose of the interviews was to take student opinions about teaching-learning method. In the interviews, 125 students attended 554 times. The responses were categorized in six main topics: influences, likes, dislikes, distracters, changes, and collaborative teams (Table 7). HSF was found as the highest influencing factor (93.6%) for female and male students' scores. The students distracted by other classes (24%). Also they declared that they learned too much information in very short time. They mostly liked not having hands-on activity assignment outside studio classroom (96%). While the students mentioned several changes which they felt could improve the studio, they only mentioned about time deficiency for completing assignments as a "dislike" (58.4%). In the topics which they have difficulty to understand, they get help from their team members.

Conclusion

In present study, an investigation was conducted with hybrid studio format "HSF" in the Introductory Calculus-Based Physics II for two semesters (Fall 2008 to Spring 2009) to 'monitor' the strategies that students use and their attitudes, opinions in problem solving process on

LON-CAPA; ‘to enhance’ the format of the course by giving the students a better learning experience by finding out their opinions; ‘to probe’ how well the student felt HSF met criteria such as coordination between lecture, homework, and hands-on activity work; ‘to learn’ student’s approaches to the exam questions, if they use the strategy that they learned in the course and comments to improve HSF. The findings indicated that HSF encouraged students to use the problem solving strategies while solving a problem with the total increases of 22.05% in F08 and 21.04% in S09. Also, HSF improved the students’ positive attitudes toward problem solving such as increasing students’ self confidence on problem solving. The students had high performances in all activities (Average grade ≥ 60). The lowest score was obtained on their exams. LON-CAPA score reflected higher performances because the system had some advantages over other activities. This might have been caused by some persistent students who could get the correct answer by entering a numerical answer multiple times with a trial-and-error strategy. Therefore, to overcome this drawback, some technical modifications for LON-CAPA were proposed such as automatic feedback, less number of attempts, and incorporation of simulations. The students declared in the interviews and surveys that they liked the opportunity for one-on-one interaction with instructors, collaborative study, checking the problems on LON-CAPA. Further, the students felt that connections between the homework, hands-on activity, and lecture parts of the course were clear and obvious.

Consequently, HSF was observed as an effective teaching/learning method by converting novice students to more experienced students. The student-centered activities also offered a friendly lecture to students and even to those instructors who sometimes tend toward the traditional style of classroom. HSF provided an excellent opportunity to introduce large scale undergraduate level courses to students in an interactive learning environment with its technology and team-based learning.

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Appendix A. Problem solving strategies survey (PSSS).

Items		Factor loadings		
		Factor 1	Factor 2	Factor 3
1	I limit the given data in the problem.	0.758		
2	I tabulate the given and asked variables in the problem.	0.725		
3	Drawing pictures or imaging real physical situations help me do physics.	0.724		
4	I try to understand the problem before solving it.	0.707		
5	I think of the related variables in the problem.	0.706		
6	I try to remember related equations.	0.664		
7	I visualize the problem.	0.653		
8	If I am given the problem quite a bit different from the examples in the book, I can figure it out myself.	0.639		
9	I define the concepts of the problem.	0.564		
10	I restate the problem in my own words.	0.563		
11	I read the problem more than once to make sure I understand it.	0.538		
12	After reading the problem, I try to remember if I have ever done a similar problem before.	0.522		
13	I review the related principles of the problem.	0.498		
14	I focus on the problem's solution.		0.763	
15	I divide the problem into sub-problems.		0.694	
16	I put the given variables on the related-equations.		0.693	
17	I use the trial and error method to find a solution.		0.668	
18	I try to solve the problem with a similar one.		0.615	
19	I can think of at least one way to begin to work on a problem that I've never seen before.		0.570	
20	I interpret the results obtained from a problem.			0.883
21	I check my calculations for errors.			0.817
22	After I have solved a problem, i try to think of a different way to solve it.			0.805
23	I check the answer if it is reasonable.			0.699
24	I make the dimension analysis for the solution			0.594
25	I examine the solution steps.			0.537
Eigen values		8.45	7.81	7.29
Variance explained		24.12	22.03	17.71
Cumulative proportion of variance explained		24.12	46.15	63.86
Cronbach's Alpha values		0.80	0.81	0.85

Note: [1]Factor 1: Identifying the fundamental principle(s), Factor 2: solving, and Factor 3: checking; [2]Loading of less than 0.40 was eliminated; [3]Cronbach's Alpha value of PSSS was found as 0.86; [4]The scores of each item ranged from 1 (never) to 5 (very often).

Appendix B. Attitudes toward problem solving survey (APSS).

Items		Factor loadings	
		Factor 1	Factor 2
1	I usually believe that I can solve a problem.	0.847	
2	I enjoy solving problems that require me to figure out my own individual approach.	0.818	
3	I like to solve a problem.	0.816	
4	I enjoy exploring physics relationships.	0.807	
5	I can solve problems easily.	0.803	
6	I like to discuss a problem.	0.748	
7	I like to interpret a problem and its solution.	0.679	
8	I am usually enthusiastic about solving a problem.	0.647	
9	When I am working on challenging problems, I feel frustrated.		0.796
10	I have trouble getting started on a problem that is new to me.		0.754
11	Preconceptions prevent me from solving a problem.		0.741
12	I have difficulty in solving a problem.		0.704
13	I lose self confidence if I cannot solve a problem.		0.687
14	I'm stressed while solving a problem.		0.656
15	When I do not know what to do, I give up.		0.592
16	I'm afraid of making numerical mistakes.		0.568
17	Reading a problem more than once is a waste of time.		0.561
18	I cannot concentrate on problem solving.		0.558
19	I am upset if I cannot solve a problem.		0.534
Eigen values		6.89	7.22
Variance explained		31.68	30.68
Cumulative proportion of variance explained		31.68	62.36
Cronbach's Alpha values		0.85	0.83

Note: [1]Factor 1: positive attitudes, Factor 2: negative attitudes; [2]Loading of less than 0.40 was eliminated; [3]Cronbach's Alpha value of APSS was found as 0.85; [4]The scores of each item ranged from 1 (strongly disagree) to 5 (strongly agree).

Appendix C. Interview questions about HSF.

1) How did you feel while taking the exam?
a) Did you understand the questions?
b) Did you think you were prepared? Why?
2) You did particularly well on this problem. Which strategy did you follow?
a) What can you think of from HSF which relates to this?
b) What else could we have done to help?
3) I noticed you did not do well on this problem. What were you thinking?
a) What can you think of from HSF which related to this?
b) What else could we have done to help?
4) Think about the course and the exam. What from the course influenced you while you were taking the exam? a) What could we do to do better job?
5) What about the course distracts you from learning what you would like?
6) Let's consider HSF by itself for a moment.
a) How do you feel about HSF now compared to the beginning of the semester?
b) What do you like about HSF?
c) How do you like working in collaborative teams?
d) What do you dislike about HSF?
e) What changes would you make?
7) Do you have any further comments you want to make?