Just-in-Time Teaching (JiTT): Using the Web to Enhance Classroom Learning

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Abstract

Just-in-Time Teaching (JiTT) is a pedagogical system that uses the WWW to enhance learning in the classroom setting. JiTT was developed for use in the introductory physics classes taken by engineering majors at IUPUI and the US Air Force Academy, but its use has spread to a wide range of fields and institutions. At IUPUI, JiTT is now used in physics, biology, chemistry, mathematics, sociology, and writing. Elsewhere, in the US, Europe, and Israel, over 100 instructors are using JiTT methods.

The JiTT system is built around web-based preparatory assignments that are due a few hours before class. The students complete these assignments at their own pace and submit them electronically. In turn, faculty adjust and organize the classroom lessons in response to the student submissions "Just-in-Time." This establishes a feedback loop between the classroom and the web. The feedback cycle occurs several times each week, encouraging students to stay current.

At IUPUI, we have been testing and revising the JiTT method for twelve semesters and are encouraged by the results. Working with the JiTT strategy has convinced us that the web, combined with live teachers in the classroom, can humanize instruction for all students and make a real difference in results, particularly for at-risk students. At IUPUI, attrition in our introductory physics courses has declined by over 40%, and the numbers of students choosing physics as a major or minor has risen significantly. When asked their preferences in post-course surveys, over 90% of students expressed a preference for JiTT over traditional course formats.

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Introduction

Many businesses use "Just-in-Time" methods to enhance the flexibility and responsiveness of their operations.[1] Various parts of the enterprise communicate their needs to one another frequently, and only the necessary materials or products are delivered. Such systems rely on rapid communications technology and on distribution systems that make small, frequent deliveries. In this way, each delivery is smaller, and contains only those materials needed for short term operations, rather than large, infrequent deliveries based on average needs determined long in advance. We have developed a pedagogical system that we call “Just-in-Time Teaching” or “JiTT” in analogy with this method.[2] Like the business model on which it is based, JiTT increases flexibility and responsiveness. Class time is used more effectively, because less time is spent on material students have learned from reading, and more time is available to concentrate on more difficult subjects. Students have greater control of their learning, and are more motivated and engaged as a result.

In a JiTT environment, students and instructors communicate with one another outside of class time, and the information is used to adjust the content and format of the classroom lesson. Just as in the business context, there are many ways in which this system can be implemented; the details depend on the nature of the course and the preferences of the instructor. For instance, the communication can be synchronous, asynchronous or a mix of both. All of the communications may be between the instructor and individual students, or students may work in teams that communicate internally. The process may occur daily, or at other specified intervals.

This paper will describe the challenges that Just-in-Time Teaching addresses. It will describe the principles upon which JiTT is founded, and it will describe how JiTT is applied, drawing examples from courses taught by the authors at IUPUI. It will also include assessment data based on student performance and attitudes.

To avoid confusion, the authors would also like to stress what JiTT is not. Despite the heavy use we make of the WWW, JiTT is not a distance learning system. All of our courses have regular classroom meetings. Indeed, the focus of JiTT is on enhancing, not reducing, face-to-face meetings among students and faculty. JiTT is also not “Just in Time Training.” This phrase is often used to describe systems in which employees access online training materials or attend seminars relating to new skills or equipment “just in time” for continued operations.[3] Finally, we would like to stress that JiTT is not a method for reducing faculty workloads. JiTT is compatible with, but does not rely on, intelligent tutors or other means of computer-aided instruction.

Challenges

At the outset, JiTT was developed to teach introductory physics at two very different institutions: IUPUI and the United States Air Force Academy (USAFA). IUPUI is a large, urban university with substantial numbers of non-traditional students. IUPUI students have an average age of 27, over 90% commute to IUPUI, and they work an average of 25 hours per week off campus. Furthermore, many IUPUI students are the first in their families to pursue a higher education, and most were poorly prepared by the secondary school system. The students in IUPUI’s calculus-based physics sequence are predominantly engineering majors. In contrast, USAFA is a four-year college in a rural setting. Its students are all full-time, and most have excellent educational backgrounds. However, USAFA students are Air Force cadets, and have substantial military duties. Furthermore, all cadets are required to take calculus and physics, regardless of major.

As a result, physics faculty at IUPUI and USAFA faced similar challenges for very different reasons. Students were not committed to learning physics. They considered it a distraction from more important pursuits, and were not engaged in their learning. Unsurprisingly, faculty were dissatisfied with student performance, and students resented having to take physics at all. JiTT was developed to meet these challenges and others as well. In addition to improving student performance and satisfaction, JiTT also helps students develop good study habits, includes an increased emphasis on writing skills, and helps students learn to deal intelligently with large or poorly defined problems.

Principles

JiTT is firmly grounded in education research. For instance, in the recognition that students learn best when they are actively engaged rather than passive.[4, 5, 6] JiTT helps establish interactivity in the classroom, even in a large, theater-style environment. JiTT also recognizes that students are most successful if they study a subject frequently, in sessions of moderate length, rather than in infrequent "cram sessions."[7, 8] By introducing several small assignments in addition to traditional problem sets, JiTT helps encourage students to pace themselves appropriately. JiTT also strives to create an environment that is student-centered,[9, 10] and in which students feel a degree of ownership over the learning process. Alexander Astin has identified three "critical factors" for students' success in higher education. These are (1) Student-Student interaction, (2) Student-faculty interaction, and (3) Time on task.[11] Just-in-Time Teaching intentionally focuses on increasing the quantity and quality of each of these factors.

JiTT also recognizes several more basic principles. For instance, JiTT is grounded in the notion that education works best when faculty are aware of students needs and abilities, and react accordingly. JiTT also recognizes the fundamental truth that "students learn what students do." If students are to learn technical writing, teamwork, and the ability to address large questions, they must be asked to do these things.

Methods

Just-in-Time Teaching relies on a combination of high-tech and low-tech methods. On the high-tech side, the WWW is used as a flexible, high-speed communications tool linking students and faculty. On the low-tech side, students participate in several classroom activities that stress active learning and interaction among students and faculty. In the recitation sections, student teams work on problems under the guidance of faculty and peer mentors. We have also developed an "interactive lecture" unique to JiTT. There is also a traditional laboratory session once each week. This section will give a brief description of several web-based tools and assignments used at IUPUI. One of these, the WarmUp exercise is a crucial element in the interactive lecture method.

WarmUp Exercises are the single most important element of the Just-in-Time Teaching strategy. These are brief, conceptual exercises that are due before lecture periods. Students must read assigned materials, then answer several questions via an online form. In the introductory physics courses at IUPUI, the WarmUps are due two hours before each lecture session. Although this period can be varied substantially, it should be short enough that the subject is fresh in the students minds (12 hours or less) yet long enough that the instructor has time to review a representative sample of the students responses (at least 1 hour). Grading of the WarmUp exercises is also subject to the instructor's discretion. At IUPUI, most instructors grade the

WarmUps on effort, rather than for technical accuracy. This encourages students to participate fully, and is especially helpful when the WarmUp focuses on subjects that are difficult or confusing. This also helps maintain student motivation. Students resent being graded on material that has not yet been discussed in class.

In the period between the submission deadline and the class period, faculty adjust and organize the classroom lesson in response to the students' submissions "Just-in-Time." Thus, a feedback loop between the classroom and the Web is established. The WarmUps encourage students to keep up in the textbook, and are designed to challenge students' preconceptions about the subject. To use the WarmUps, we read the students' submissions and select excerpts that will be used in class.

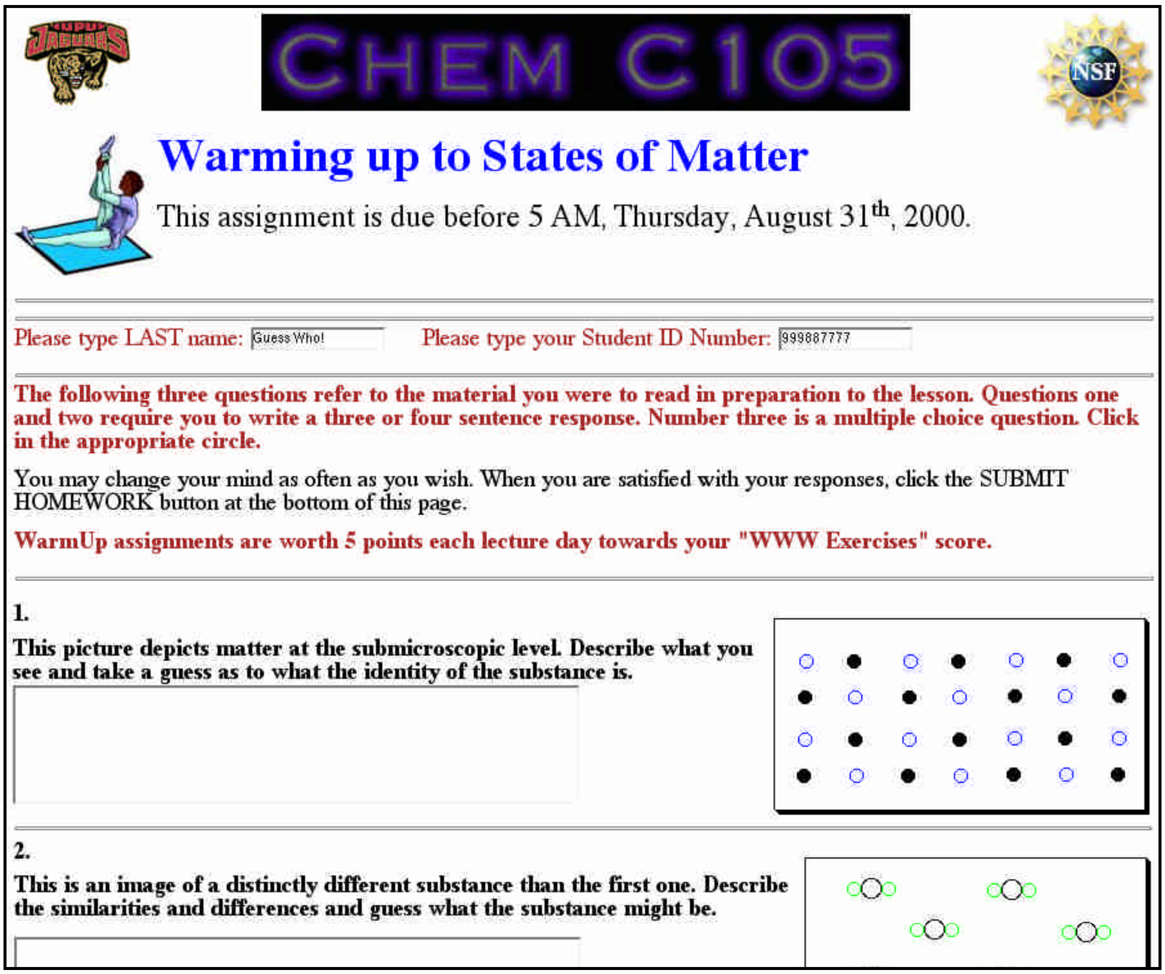


Figure 1. Excerpt from a WarmUp exercise on "states of matter" used in a general chemistry course at IUPUI.

During the **Interactive lecture**, we present the excerpts selected from the students work, weaving them into the presentation as appropriate. Instead of passively listening to a lecture, students participate in a guided discussion that begins with their own preliminary understanding of the material. We do not simply "go over" the questions in an isolated section of the lecture; rather, we frame our lecture in terms of an analysis of various student responses**.** It is noteworthy that the instructor need not read all of the students' responses for this purpose. Reading a few dozen responses generally provides adequate material for the lecture, and grading may be done later, possibly by a teaching assistant or student mentor. Figure 1 shows an example of a WarmUp Exercise used in a general chemistry course at IUPUI.

Building the lecture around students' responses has numerous benefits. It is far easier to elicit students' thoughts on a subject if the discussion is grounded in their own work. The WarmUps encourage students to prepare for the lecture, and help them develop a "need to know." If many of the students have not understood a particular point in the reading, the faculty member is forewarned, and can give more attention to that point. If a point has clearly been understood by most of the class, then that issue can receive less emphasis.

This method does not lead to sacrificing content. The instructor designs the questions and selects which student responses to use in class. With a little practice, the instructor can easily elicit responses that are good "talking points" for the material he wants to cover.

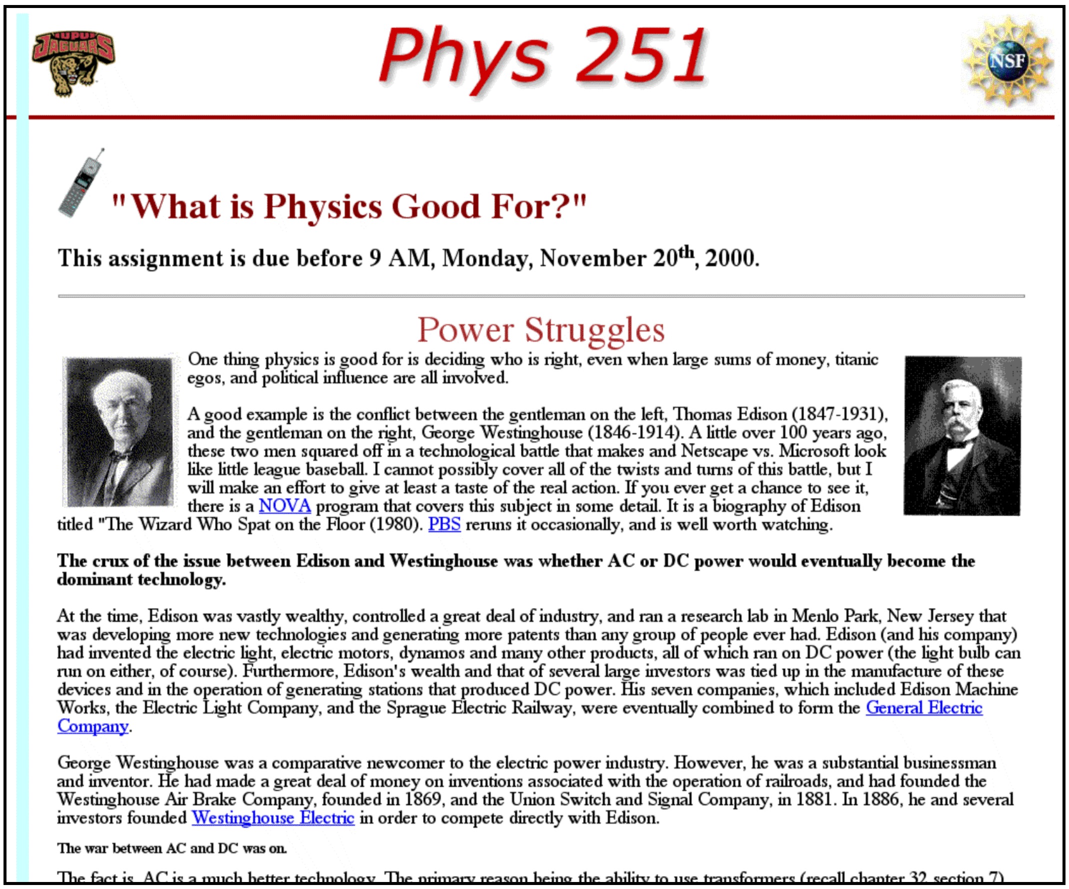
A key aspect of the interactive lecture is to use the WarmUp responses to promote active learning during the lecture, a particularly difficult task in large, theater-style rooms. However, using the WarmUps carefully, it is possible to engage students even in classes of several hundred students. There are many ways to accomplish this goal. Most involve brief periods in which students discuss the subject with their "neighbors" in the classroom. For instance, students can be shown two responses to the same question which are clearly mutually exclusive. The instructor asks the class for a show of hands on which (or neither) of the answers is correct. After noting the result, she then gives the students two minutes to discuss the two answers with their neighbors before asking for a new vote.

This process is rooted in the "Peer Instruction" technique developed by Eric Mazur.[12] In his classes at Harvard, Mazur punctuates his presentations with *ConceptTests*: brief, usually multiple choice questions on the topic under discussion. Students are given an opportunity to think about the *ConceptTest*, record individual answers, then discuss the *ConceptTest* with their neighbors. This system is often used in conjunction with classroom response systems such as Classtalk and CPS.[13] Mazur has also worked to combine his methods with the JiTT strategy, as described in his Project Galileo web site.[14]

We have also found that using the WarmUps helps students to improve their study habits. Because WarmUps are due on lecture days (and homework on recitation days) our students have assignments due on every day of class. This encourages them to organize their studying around manageable sessions, through which they can remain alert and effective.

What is Physics Good For? (or What is Biology Good for?, What is Chemistry Good For?, etc.) This is an essay, usually of 100 words or less, written by the instructor on a variety of subjects. They are generally assigned weekly. They tend to focus on familiar applications and phenomena such as lightning storms, telephones and telegraphs (in physics) or materials development and drug design (in chemistry). In biology courses, they often focus on medical applications. Each essay includes numerous links to further information on the subject and concludes with several research questions, which students answer for course credit.

We use these essays for several reasons.[15] They are an excellent opportunity to enrich the course. Many courses have a wide syllabus that must be covered, as the skills and information presented are essential prerequisites for more advanced science or engineering courses. Frequently, instructors have many subjects to cover in a limited amount of time, so there is little opportunity during lecture for material one might consider to be extraneous. The "Good For" provides an opportunity for students to delve into interesting subjects outside of the lecture period. An excerpt from a "What is physics Good For" essay is shown in Fig. 2. This essay, on the conflict between Thomas Edison and George Westinghouse, describes events with a human and historical dimension that is usually left out of introductory courses.



Phys 251

"What is Physics Good For?"

This assignment is due before 9 AM, Monday, November 20th, 2000.

Power Struggles

One thing physics is good for is deciding who is right, even when large sums of money, titanic egos, and political influence are all involved.

A good example is the conflict between the gentleman on the left, Thomas Edison (1847-1931), and the gentleman on the right, George Westinghouse (1846-1914). A little over 100 years ago, these two men squared off in a technological battle that makes and Netscape vs. Microsoft look like little league baseball. I cannot possibly cover all of the twists and turns of this battle, but I will make an effort to give at least a taste of the real action. If you ever get a chance to see it, there is a NOVA program that covers this subject in some detail. It is a biography of Edison titled "The Wizard Who Spat on the Floor (1980). PBS reruns it occasionally, and is well worth watching.

The crux of the issue between Edison and Westinghouse was whether AC or DC power would eventually become the dominant technology.

At the time, Edison was vastly wealthy, controlled a great deal of industry, and ran a research lab in Menlo Park, New Jersey that was developing more new technologies and generating more patents than any group of people ever had. Edison (and his company) had invented the electric light, electric motors, dynamos and many other products, all of which ran on DC power (the light bulb can run on either, of course). Furthermore, Edison's wealth and that of several large investors was tied up in the manufacture of these devices and in the operation of generating stations that produced DC power. His seven companies, which included Edison Machine Works, the Electric Light Company, and the Sprague Electric Railway, were eventually combined to form the General Electric Company.

George Westinghouse was a comparative newcomer to the electric power industry. However, he was a substantial businessman and inventor. He had made a great deal of money on inventions associated with the operation of railroads, and had founded the Westinghouse Air Brake Company, founded in 1869, and the Union Switch and Signal Company, in 1881. In 1886, he and several investors founded Westinghouse Electric in order to compete directly with Edison.

The war between AC and DC was on.

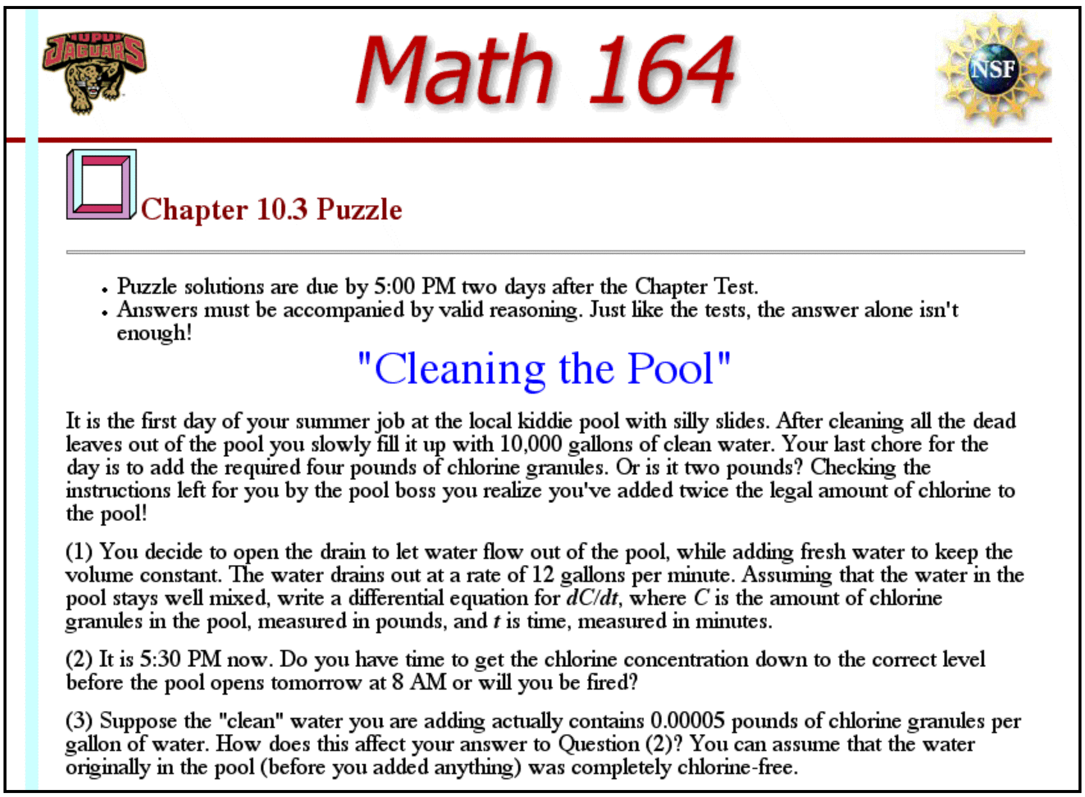
The fact is, AC is a much better technology. The primary reason being the ability to use transformers (recall chapter 32, section 7)

Figure 2. An excerpt from a "What is Physics Good For?" essay used in an introductory physics course at IUPUI

These essays also provide motivation to strong and weak students alike. Through careful selection of topics, theses essays also help to connect the subject matter to "real life." Even the best students occasionally ask themselves "why am I being asked to learn this? Will I ever use this in my career?" This essay addresses these questions on an ongoing basis, helping students stay motivated.

Puzzles act as the opposite "bookends" to the WarmUp exercises. Like WarmUps, puzzles are delivered and answered via the WWW. However, where we use WarmUps to introduce individual topics and subtopics, we use Puzzles to tie a group of topics together, and to connect those topics to prior parts of the course. Puzzles are intended to be difficult even for the best students in the class. They often ask students to integrate course content with knowledge from other courses, and they are usually graded much more harshly. Most instructors use puzzles less frequently: once each week or less.

In the classroom, we treat the puzzles in much the same way that we do the WarmUps. Faculty take excerpts from students responses and bring them to class for use during the discussion of the puzzle. Unlike WarmUps, however, puzzles are usually discussed in isolation, at the beginning of class. Once the discussion of the puzzle is ended, we move on to introduce new material.



Math 164

Chapter 10.3 Puzzle

- Puzzle solutions are due by 5:00 PM two days after the Chapter Test.
- Answers must be accompanied by valid reasoning. Just like the tests, the answer alone isn't enough!

"Cleaning the Pool"

It is the first day of your summer job at the local kiddie pool with silly slides. After cleaning all the dead leaves out of the pool you slowly fill it up with 10,000 gallons of clean water. Your last chore for the day is to add the required four pounds of chlorine granules. Or is it two pounds? Checking the instructions left for you by the pool boss you realize you've added twice the legal amount of chlorine to the pool!

(1) You decide to open the drain to let water flow out of the pool, while adding fresh water to keep the volume constant. The water drains out at a rate of 12 gallons per minute. Assuming that the water in the pool stays well mixed, write a differential equation for dC/dt, where C is the amount of chlorine granules in the pool, measured in pounds, and t is time, measured in minutes.

(2) It is 5:30 PM now. Do you have time to get the chlorine concentration down to the correct level before the pool opens tomorrow at 8 AM or will you be fired?

(3) Suppose the "clean" water you are adding actually contains 0.00005 pounds of chlorine granules per gallon of water. How does this affect your answer to Question (2)? You can assume that the water originally in the pool (before you added anything) was completely chlorine-free.

Figure 3. *A puzzle on separable differential equations used in a calculus course at IUPUI*

Intra-class communications are aided by several online tools including an anonymous "suggestion box," a course bulletin board, and an "announcements" feature on the course home page. The first of Astin's three factors is student-student interaction. At residential colleges and universities, this interaction is facilitated by students living arrangements. Dormitories and other student housing often have common study areas in which students can find peers who are taking or have taken the courses that they are struggling with. They often learn more while working with such colleagues than they do during class time. Unfortunately, this type of interaction is unavailable to part time or commuting students. We use an online bulletin board for each course in an effort to at least partially obviate this lack. In addition to the bulletin board. The course web sites also each contain an anonymous electronic ‘suggestion box” through which they can communicate concerns to the instructors without fear of reprisal. This gives us the opportunity to receive valuable feedback throughout the semester rather than waiting for the official course evaluations which are not available until the semester ends.

The recitation section has been substantially changed as well. In the traditional format, an instructor (often a graduate student) would present detailed solutions to the homework problems. The class size was smaller, but student participation was as limited as in the traditional lecture. We have replaced this session with one in which the instructor spends only the first ten to fifteen minutes of class discussing the homework, often focusing on a single difficult problem. For the remainder of the class, students stand at whiteboards (which cover much of the available wall space) and work on problems in teams of two to four. The instructor, a graduate student, and several peer mentors circulate throughout the room during this time, providing help as needed.

Assessment

We have assessed the effects of Just-in-Time Teaching on retention, student attitudes and on cognitive gains. Our efforts thus far have included a range of instruments including surveys, pre/post–tests, and classroom observations. Some of these instruments are anonymous, in others, students identify themselves using student ID numbers, so we can correlate their responses on these instruments with other information such as course grades, demographics, and enrollment status.

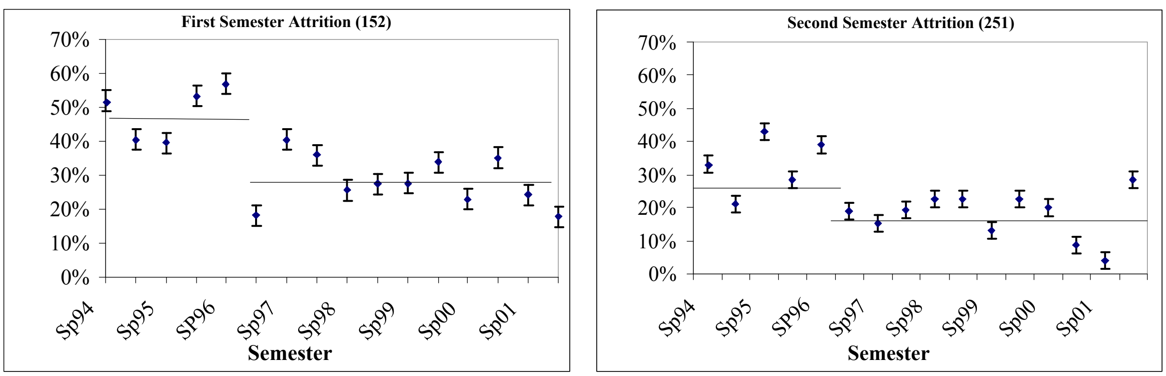
Most of the results are encouraging, indicating that students are pleased with the web-based elements, are willing to spend time on them, and consider them useful, e.g., 80- 90% would choose to keep the web-based elements rather than substitute a traditional course. Other results are less encouraging, indicating, e.g., that many students develop good study habits during the course, but that they do not translate these habits into improved attitudes towards future work. We will present some of our results here, focusing on data from the physics courses in which the project was initiated.

When we began developing the JiTT method, one of our first goals was to reduce attrition in the calculus based physics sequence. These courses had previously been taught by several instructors in a traditional lecture-section-lab format. Attrition as measured by the percentage of students withdrawing or receiving a grade below C- was at an unacceptable level, even considering the large numbers of at-risk students we teach at IUPUI. The “DWF rate” averaged almost 50% in the first semester course, and almost 35% in the second semester.

In the fall of 1996, one of the authors (AG) and another instructor, Dr. G. Novak, took over the first course in the sequence. In spring of 1997, the second course in the sequence was added to the project. During these two semesters, we established course web sites and began offering basic course information, WarmUp exercises, and a weekly puzzle. We also instituted the use of collaborative problem solving exercises in the recitations at that time. “What is Physics Good For?”, electronic bulletin boards, and other web-based features were added later.

Our results in reducing attrition in the physics courses has been striking. Figures 4 (a) and (b) show, respectively, the DWF rates for introductory mechanics (PHYS 152) and electricity and magnetism (PHYS 251). In each case, The horizontal lines reflect the periods before and after JiTT methods were adopted.

We would like to stress that these results do not reflect reduced standards or instructor effects. Throughout the period shown, both courses have maintained a strict policy that students automatically fail if they receive less than 50% total scores on the mid-term and final exams. These exams are reviewed by other department faculty, including those who had been teaching the course previously. Furthermore, five different faculty members have been involved in teaching these courses since the JiTT method was firmly established in 1998. The improved results using JiTT persist regardless of whether or not the course is taught by one of the original developers of the method.



(a) (b)

Figure 4. DWF rates for (a) introductory mechanics and (b) introductory electricity and magnetism at IUPUI.

We also gather self-reported information on students study habits. For instance, students in biology N100 (a large survey course intended for non-science majors) were asked three questions concerning study habits:

1) Do you feel that the WarmUp assignments and other web assignments caused you to stay ‘caught up’ on class material?
2) Do you put off studying for N100 and as a result ‘cram’ for N100 tests on the night before the test?
3) Do you cram for other courses that you have this semester?

We have broken down there responses of N = 155 students based on course grade (as predicted by the three mid-term exams). The results are summarized in Table 1.

Table 1: Student reported data on study habits by predicted grade in a biology course at IUPUI

	1 – Yes	2 – Yes	3 – Yes
'A' Students	85%	14%	43%
'B' Students	89%	39%	61%
'C' Students	89%	47%	68%
'D' Students	84%	68%	68%
'F' Students	92%	58%	58%

According to students' reports of their study habits, the use of WarmUps has a clear beneficial effect in helping students stay caught up with the material. Over 80% of students reported this at all grade levels. However, when asked whether students "cram" for exams, there is a clear differentiation depending on student's performance. The best performing students reported that they "crammed " at significantly lower levels for the JiTT based course than they did in their other courses during the same semester. Students at the lower end of the grade scale reported no difference in their behavior in the JiTT course than in other courses.

These results must be considered with some caution. We also probed students' attitudes concerning study skills using a Likert-scale survey conducted in a pre/post–course mode. We formed a group of 6 questions on study skills such as "I usually work a little each day to keep up with the readings and assignments." and "I usually read all assigned material before it was discussed in class." This group of questions showed no statistically significant change between the pre-course and post-course tests, either in aggregate or broken down by grade level.

We attribute much of our students improved performance to the results of improved attitudes and study habits. Students attitudes, in particular are often downplayed as unimportant "affective" measures of course performance. However, we believe that if students are happier with a course, and believe that it is structured with their success and participation in mind, they will devote greater effort to that course. Time on task is greatly enhanced if students maintain a positive attitude towards the course.

We measured students attitudes towards several of the web-based components of our courses using anonymous web-based surveys. Some of the results are reproduced in Table 2. Students were asked "Are the WarmUps a good idea? Why or Why not?," and "If you could pick your instructor, and you had a choice between two equal instructors, except that one instructor used WarmUps and the other didn't, which instructor would you pick?" Questions of this form were asked concerning the WarmUps, the "What is Physics good For?", and the Puzzles. Students were also asked if they thought the collaborative work was a good idea in recitation, and given a choice between a recitation stressing collaborative work vs. a recitation in which instructors solved all of the homework problems in detail. These results were compiled over three semesters. Students were asked to respond after completing the Physics 152-251 sequence. 88 students participated, out of 129 who completed the classes.

Table 2: Students attitudes about various JiTT course components.

Question	Yes (%)	No (%)	Neutral (%)
WarmUps: a good idea	88	8	4
WarmUps: picked	78	13	9
Good For: a good idea	87	0	13
Good For: picked	85	2	13
Puzzles: a good idea	82	1	17
Puzzles: picked	79	0	21
Collaborative sessions: a good idea	96	2	2
Collaborative sessions: picked	91	7	2

These overwhelmingly positive results, and their relationship to improved performance, are supported by the text comments students added. The following are typical (and unedited) comments made by students in response to this survey.

On WarmUps: They encourage students to think through the concepts, not just try to do the math." "Since I have a tendency to put things off, the 'warm-ups' were a great way to get me to read ahead for lecture." "It helps you to get an idea of the main points your going to talk about that day in lecture." "I think all of these tools are additional teaching formats and I think that it has kept me focused on physics because I always had something due every day."

On "What is Physics Good For?": "I definitely like the Good Fors. It relates the lecture to actual, pertinent real world subjects. It is scary, I am beginning to really like physics, because of the Good For." "The 'What is physics good for?' questions are a good idea. When you are learning a difficult subject such as this one it is interesting to see how the physics you are learning can be applied to everyday life. It makes learning the subject material much more interesting when you can see how it applies to your life." "I would pick the instructor who uses the questions because I think things are much more interesting when you see how they apply to your life. It makes you want to learn more about the subject."

On Puzzles: "The best thing about it, is that is gets the mind stimulated. Some were pretty tough." "The puzzles are a good idea. All of these things are good ideas from the mere point that the more exposure a student gets to a subject the more information he will retain." "Puzzles are a nice concept because they always deal with a difficult part of the current material we're studying so again if we can understand the ideas and concepts behind a puzzle then everything else in that current section should be easy."

On Collaborative exercises: "I think it is quite remarkable the amount of resource, time and effort the Physics department has invested in the recitation program . No other department does this on campus." "The best part is the extra help we can get from instructors. Solving problems can definitely be approached from different angles, and the recitation board-work helps us see that. It provides a relaxed atmosphere for both students and teachers. I actually found myself laughing with my group, as we were doing board-work."

"it gives students a chance to get to know their professors, and the professors a chance to interact with students and observe their problem solving skills or lack their of."

Conclusion

Just-in-Time Teaching is an effective means of improving student attitudes and performance in a variety of science and mathematics classes. By using the WWW as a communications tool, JiTT helps instructors engage students in their learning. JiTT can be used to promote an interactive, student centered environment in the classroom, and can help instructors fine tune their courses to match students' needs.

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