Just-in-Time Teaching: Potential Uses in Mechanics Courses

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Abstract

Over the last 8 years, the physics educational community has developed a new learning strategy known as Just-in-Time Teaching (JiTT). In this approach, students are required to answer short questions posted on the web at least two hours before class. Questions are typically more open-ended and conceptual rather than mathematical. The instructor then reads through the student answers before class and tailors the classroom experience based on student understanding. For new topics, many students will appreciate some aspects of the idea, but different students will grasp different aspects of the subject matter. By presenting the answers from different students the instructor can build up an understanding of the complex idea. In this way, students feel greater ownership of the course, come better prepared to class, and have more productive interactions with the professor. Examples of the use JiTT in undergraduate physics will be presented and a framework for applying the techniques to Mechanics described.

Introduction

The physics educational community has long been at the forefront of innovative pedagogy. Instructors have developed interesting hands-on demonstrations, laboratories, and examples top help motivate and teach their students. The Force Concept Inventory(1) has been used for a decade to help determine if students are really grasping the underlying physics principles; many different engineering disciplines are now borrowing the idea of concept inventories. Just in Time Teaching (JiTT) is another concept that could greatly benefit the engineering educational community.

Only recently has the JiTT concept been reported in the engineering educational literature(2,3). Freshman physics lays so much of the foundation for engineering dynamics that it only seems natural to borrow some of the innovative work done in physics education for mechanics purposes. In order to help facilitate this process, we will first provide an introduction to the basic components of JiTT and its underlying educational theories. Examples of mechanics modules will then be provided, with representative answers and how the instructor modified the lesson as a result of the student input. Finally, references and advice on how to utilize JiTT will be supplied to potential users of the technique.

The Just in Time Teaching Approach

JiTT should not be confused with other uses of "Just-in-Time" that is prevalent in the engineering literature. Other authors use JIT to represent presenting material just before it will be used, for example in a laboratory exercise or an assigned project. JiTT, on the other hand, is a technique used to enhance the interactivity of a lecture period by creating a feedback loop between the instructor and the student.

The JiTT strategy reflects recent efforts in cognitive psychology, developmental psychology, social psychology, anthropology, neuroscience, as well as education research in general and in specific disciplines, such to understand how people learn. A recent report by Bransford[(4)] discusses what principles of knowledge organization underlie people's problem solving capabilities, how people transfer learning in one setting to another, and how these results can be used to design new and better learning environments. His team recommends three facets for a successful learning environment.

Centering on the learner
"Learner-centered teachers present students with "just manageable difficulties" -that is, challenging enough to maintain engagement, but not so difficult as to lead to discouragement. They must therefore have an understanding of their students' knowledge, skill levels, and interests."[(4)]

Centering on assessment
"Ongoing assessments designed to make students' thinking visible to both teachers and students are essential... An important feature of assessments in these classrooms is that they be learner-friendly: they are not the Friday quiz for which information is memorized the night before, and for which the student is given a grade that ranks him or her with respect to classmates. Rather, these assessments should provide students with opportunities to revise and improve their thinking, help students see their own progress over the course of weeks or months, and help teachers identify problems that need to be remedied (problems that may not be visible without the assessments)."[(4)]

Centering on knowledge
"The content knowledge necessary for expertise in a discipline needs to be differentiated from the pedagogical content knowledge that underlies effective teaching. The latter includes information about typical difficulties that students encounter as they attempt to learn about a set of topics; typical paths students must traverse in order to achieve understanding; and sets of potential strategies for helping students overcome the difficulties that they encounter... Pedagogical content knowledge is not equivalent to knowledge of a content domain plus a generic set of teaching strategies; instead, teaching strategies differ across disciplines."[(4)]

JiTT really encompasses all three of these strategies, and accomplishes this by using three primary tools: WarmUp Exercises and Puzzles, Enrichment Pages, and tutorials.

WarmUp Exercises
The WarmUp exercises are the heart of JiTT. Before the class period, students are required to complete short web based exercises based on their assigned reading. These questions should be closely linked to what the instructor hopes to accomplish in class, and are usually more conceptual in nature. Many instructors use the following format for their questions (although this is by no means mandatory): one multiple choice question, one essay format, and one estimation problem. The best questions ask the student to analyze a real world example, which will hopefully help develop critical thinking skills. The key is that the student answers to these problems are then used to shape the lecture.

The students should complete the web assignments prior to two hours before class to provide the instructor enough time to review their answers. From the student responses, the instructor can determine if certain material needs to be covered more in depth, if main issues can be skipped, or if supplemental reading material or tutorials need to be provided. The class time can be modified "just-in-time" to reflect student understanding and interest. Seasoned JiTT instructors use actual student answers to help build their lecture or explain a theory; they will typically put up overheads or PowerPoint slides of selected student responses. The class participants recognize their own words and feel more ownership of the course. This can also help provide confidence to students who might not normally feel comfortable interacting during class time. Even incorrect answers, if covered tactfully, can provide tremendous insight to a difficult concept.

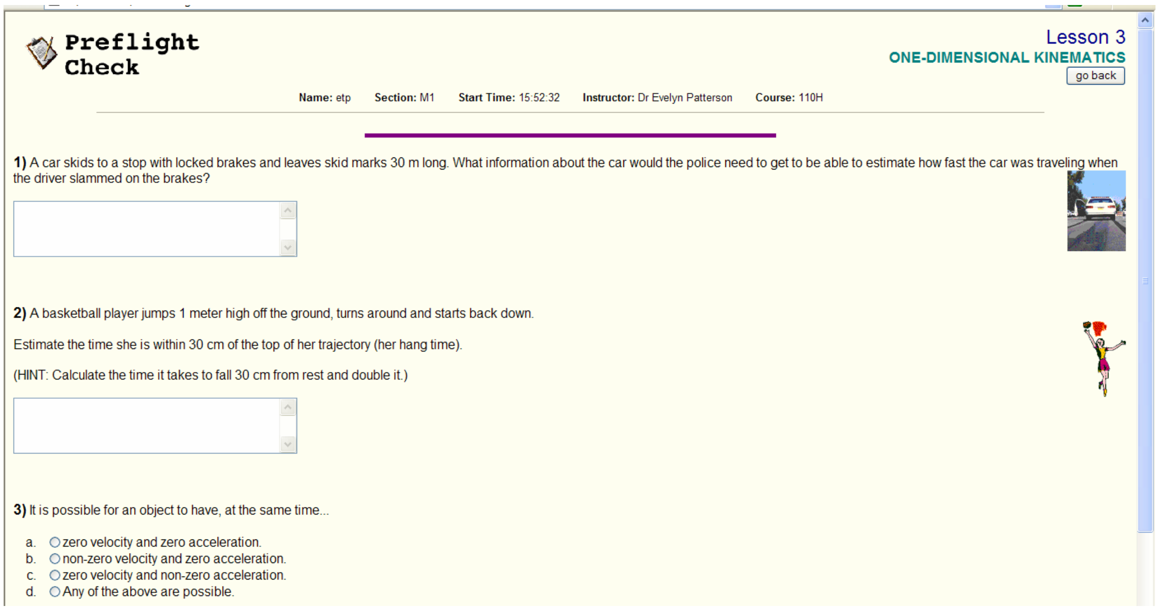
While the WarmUps are used to introduce a topic, Puzzles are used to help conclude it. Many instructors simply grade the WarmUps on effort, but Puzzles are typically graded on correctness. Puzzles are more complex, have more subtle content, and will take considerably more thought than the WarmUps. Again, the best Puzzles usually involve some type of real world application or example. The beginning of the following class time will be used to discuss the Puzzle, conclude that topic, and potentially tie the Puzzle into the next course topic.

It should be emphasized that the WarmUps and Puzzles are not meant to be simple reading quizzes that are automatically graded, nor are they computer aided instruction. JiTT is intended to create a feedback loop that drives the interactive classroom experience, enhancing the students' critical thinking, problem solving ability, and conceptual understanding.

Enrichment Pages and Tutorials
Although the WarmUps are the most essential part of JiTT, the benefits can be increased by utilizing enrichment pages and tutorials as part of the course web site. Enrichment pages are typically posted weekly, and are meant to increase student motivation and real world understanding. Topics might include current events related to mechanics (e.g., the orbital mechanics of the space station), devices in everyday life (car racing, amusement park rides, fighter jets), and historical perspectives on mechanics (Newton, Galileo). Basic student understanding of basic material can also be improved by simulation material and animated tutorials. There has been a great amount of work done on web-based tutorials in the mechanics community, much of which is presented each year at the ASEE National Conference[5-8].

JiTT Examples

An example WarmUp (at the US Air Force Academy we like to call them Preflights) is shown below. As you can see, the first question asks the student to think about making an estimation of how a real world system behaves. The second question deals with an actual calculation, but a relatively easy one. Students are expected to include their thought processes as part of their answers, and these responses provide invaluable feedback to the instructor. Finally, the third problem is more of a conceptual question that will require the student to think about what can happen physically.


Preflight Check

Lesson 3
ONE-DIMENSIONAL KINEMATICS
go back

Name: etp **Section:** M1 **Start Time:** 15:52:32 **Instructor:** Dr Evelyn Patterson **Course:** 110H

1) A car skids to a stop with locked brakes and leaves skid marks 30 m long. What information about the car would the police need to get to be able to estimate how fast the car was traveling when the driver slammed on the brakes?

2) A basketball player jumps 1 meter high off the ground, turns around and starts back down.

Estimate the time she is within 30 cm of the top of her trajectory (her hang time).

(HINT: Calculate the time it takes to fall 30 cm from rest and double it.)

3) It is possible for an object to have, at the same time...

a. zero velocity and zero acceleration.
b. non-zero velocity and zero acceleration.
c. zero velocity and non-zero acceleration.
d. Any of the above are possible.

To illustrate the use of the WarmUps and student responses, we can consider the first rather straightforward question. This WarmUp comes very early in the first semester introductory physics course, typically in the first few lessons, and deals with one-dimensional kinematics. Student responses generally fall into several broad categories. First, since the lesson topic for the day is kinematics, most student responses deal with this, but not all. Responses that are "far afield" from being on target often come from students who haven't made a sincere effort and/or students who haven't done the assigned textbook reading, as in this sample response:

> "They would need the mass of the car so as to determine its momentum. They may also want to determine the friction force the car underwent, in which case they would need the mass and perhaps the make of and wear on the tires and possibly the road condition. COMMENT: am having trouble acquiring a book. Have not done the reading yet."

Note that even this response which makes no mention of kinematics includes mention of topics that will be addressed later in the course and can be used to deliberately link to future subject matter. The response is also articulate and sensible, and these are attributes worthy of comment in class.

Another group of responses deals directly with kinematics quantities including elapsed time, such as this one:

> "The police would need to get the time it took for the car to stop. If we assumed constant deceleration, that is all we would need. We already have the beginning and end point to calculate distance, and we definitely have the end velocity. Therefore all that is needed is the time."

Such responses open up discussions about how forensic work is actually done – are stopping times part of the information acquired? In a typical class the exact student wording would be placed on an overhead or slide, and their answer dicussed.
Yet another group of responses deals with kinematics quantities with elapsed time omitted, such as this:

> "In order to solve the problem and determine how fast the car was traveling before the driver slammed on the brakes, the police first need to figure out what they already know. The police know that the final velocity was 0 and the distance traveled was 30m. Once this step is completed, find an equation that utilizes this information and has initial velocity included in it. Equation 2-11 includes all three of these factors but also includes acceleration. From this it can be determined that the police need to know what the deceleration of the car is on skidding tires in order to figure out the initial velocity."

This response is well phrased, logical, and complete. It naturally begs the question of how police would know or determine car decelerations on skidding tires, which again points to future topics in future lessons.
Other responses are similar but have different emphases, sometimes more "real world" and sometimes less. For example:

> "The policeman needs to know the mass of the car and the force the brakes apply when they are locked. Then, using Newton's laws, we know that F=ma... if the policeman knows force and mass, then he can find acceleration. Once he has the acceleration, he can use that in league with the distance the car skidded to find the initial velocity of the car coming into the skid."

This response assumes the same use of physics as the previous one, but also brings in future content – Newton's Laws and the notion of force and acceleration being related – to help answer the question of the unknown acceleration. A discussion in which such actual student responses are used as talking points encourages breadth of thinking, multiple problem solving approaches, and lots of student involvement and makes for a lively classroom!
Hopefully, the reader can see that even a "simple" question like question 1 above can elicit rich student thinking and involvement.

A more advanced example is shown in Figure 2. In this WarmUp, the students are asked to address linear momentum and its application to rockets. As many of our cadets at the Air Force Academy aspire to be astronauts, this type of WarmUp can be especially motivating. The first question asks about an astronaut during a spacewalk, while the second requires some mathematical manipulation to determine the initial acceleration of the space shuttle. Finally, a multiple choice question examines the students' conceptual understanding of linear momentum.

Preflight Check

Lesson 24

CONSERVATION OF LINEAR MOMENTUM AND ROCKETS

go back

Name: etp **Section:** M1 **Start Time:** 13:4:6 **Instructor:** Dr Evelyn E_Patterson **Course:** 110H

1) Suppose the astronaut working on the Hubble telescope got himself completely loose of the shuttle and threw away a 2 kg hammer at 2 m/s. Could the astronaut remain at rest? If not, what would determine how fast he would be moving? (What would you need to know in order to estimate or determine his speed?) Is there any way he could stop himself from drifting away?

NASA

2) The space shuttle assembly on the launch pad has a mass of about 2 million kg. The exhaust velocity of the propellant gases is about 4000 m/s. The gases are streaming out of the nozzles at the rate of about 18,000 kg/s. Given this information, estimate the acceleration of the space shuttle assembly.

3) At some point during the shuttle flight, the booster tank SEPARATES from the craft. When the connection between the two objects is severed, the velocity of the shuttle

a. increases
b. decreases
c. remains unchanged
d. the answer depends on the mass of the booster

Below is a space for your thoughts, including general comments about today's assignment (what seemed impossible, what reading didn't make sense, what we should spend class time on, what was "cool", etc.):

We can use this WarmUp to illustrate how using JiTT allows the lesson to evolve from what the *students* know and have done in preparation for the class, rather than to seem to come "from the professor." For example, to understand how rockets work, the students must first understand what momentum is, and what "conservation of momentum" means. Many student responses to question 1 above include the phrase "conservation of momentum" so a discussion and development of that topic naturally springs from using selected student responses as discussion points in class. Then a complete discussion of the rest of question 1 follows naturally as an illustration or example of the newly developed conservation of momentum concept. Question 1 also affords a nice opportunity to deal with appropriate and reasonable estimations of unknown quantities (the mass of the astronaut in a spacesuit, in this case) and frankly also often offers opportunities to inject humor into the classroom, as student responses tend to be rich and varied.

The question 1 discussion is a setup for dealing with rocket propulsion. What if the astronaut had more hammers? Or, instead of hammers, a whole series of baseballs that s/he could toss away in succession? Or a very large collection of BBs? Or a jet pack instead? In order to answer question 2, the students must understand the rocket thrust equation, which can now proceed from the question 1 lead-in. This discussion generally takes some time, but often has much of its underpinnings offered up by "snippets" of student responses to question 2. Once the rocket thrust equation has been developed by the class, some students will be convinced that their answers to question 2 are correct, but there is a hidden pitfall: many students will deal with question 2 incompletely by ignoring the external force of gravity that is acting on the entire shuttle system. This is a teachable moment. Showing representative student responses that "ignore gravity" and working through them as a class usually primes the pump for the students to self-correct during the class and realize that gravity must be considered. This then provides the opportunity to review free body diagrams, Newton's second law, and the correct solution to finding the acceleration of the shuttle assembly.

Finally, question 3 reinforces the notions of internal/external forces and if/when momentum is conserved. This deals with subtle but important uses of terminology and thorough understanding of momentum conservation. In many classes, a number of student comments (offered voluntarily in the “Comments” box below question 3 in the figure above) specifically address student thoughts about this question and its wording. Sometimes these comments suggest that discussion of question 3 should occur prior to question 2 – this needs to be decided “just-in-time” by the faculty reading the student responses.

Of course, the particular path through the content can and should depend on the exact student responses. Typically, JiTT faculty find that they are involved in considerably different classroom activities and discussions with two different sections of the same course dealing with the very same content, just because the students’ WarmUp responses suggested or dictated different approaches.

Also, it is worth mentioning that the discussion of these questions and the student responses to them can easily take up the entire lesson, when each is used broadly and extended. It certainly isn’t the case that one discusses the WarmUps in the first 5 minutes of the class to “get to the real content” – the WarmUps are designed so that their full discussion and use *is* the real content of the lesson. In physics, we often use student worksheets or other mini-activities interspersed with the WarmUp discussions, to give the students personal, hands-on practice with what we’ve developed together as a class.

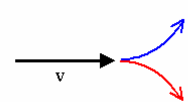
The previous two examples have shown problems that have been used in an introductory physics course; typically this same content is covered at the beginning of an engineering dynamics class. More advanced problems have been used in advanced physics courses; some examples problems that could easily be used in a dynamics course are shown below.

The following two examples examine student understanding of Coriolis acceleration.

2) Suppose you drop a ball off the top of Pike's Peak. If it could land down at sea level and *not* be affected by air resistance on the way down, about how much would its landing spot be deflected because of the influence of the Coriolis force?

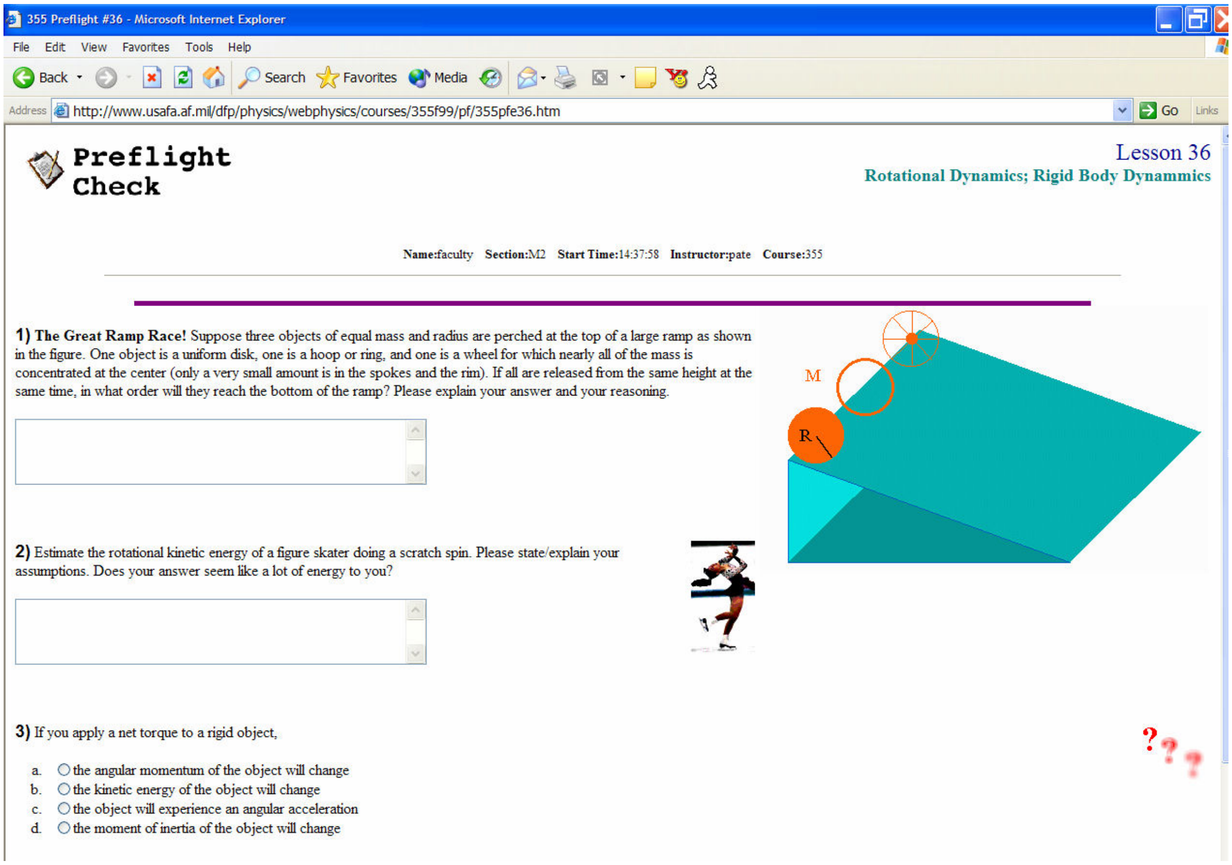
3) If you throw something while standing on the surface of the Earth, the Coriolis force will cause it to

a. ○ deflect to the left of its motion (as shown by the blue path in the figure) independent of your position on the Earth
b. ○ deflect to the right of its motion (as shown by the red path in the figure) independent of your position on the Earth
c. ○ deflect to the left (blue) of its motion in the Northern Hemisphere and to the right (red) in the Southern Hemisphere
d. ○ deflect to the right (red) of its motion in the Northern Hemisphere and to the left (blue) in the Southern Hemisphere



The lesson 36 preflight shown below tests rigid body rotational dynamics.

Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition



Finally, it is also helpful to show an example Puzzle which serves as the closure bookend to the topic at hand, as in the figure. The puzzle requires the students to go one step farther than the WarmUp questions, but is clearly related to them. Discussion of correct and incorrect puzzle responses often provides other "teachable" moments because any students who have offered answers have high interest in knowing if their answers were correct. Many times, puzzles provide opportunities to spiral back to earlier concepts (here, to kinematics or forces, for example) and at the same time to tie to future concepts (here, angular momentum and torque).

Puzzle Example

A puzzle that was assigned at the end of the linear momentum section is shown below. As you can see, this is a fairly simple application of the impulse momentum equation. Students still seem to struggle with answering this correctly, as evident by some of the representative answers below.

Some common misconceptions involving the time of the impact, the amount of elasticity in the impact, and the mass of the ball:

Letting it bounce off of you would more likely knock you off of the log because more impulse force works against you. Impulse force is momentum divided by time. When you catch it, the momentum transferred to you is spread out over more time as your body absorbs the impact. If it bounces off of you, then that same amount of momentum is transferred to your body in a very brief period of time as it ricochets back in the opposite direction.

The average impulse force of catching the ball is less because the collision takes place over a longer period of time than if you just let it hit you.

It depends upon the mass of the ball in comparison to you, if the mass of the ball is small.

Perfect inelasticity represents the minimum velocity I would experience from the collision, and any bit of elasticity would result in a slightly greater velocity.

And our favorite answer: *The best thing to do would be to duck and avoid the collision*

JiTT Implementation

Using the JiTT approach can be somewhat daunting for the first time user. It can be difficult to come up with appropriate questions, challenging to implement the questions on the web using html or other web applications, and complicated to make the classroom experience truly based on student feedback. Fortunately, the JiTT community is extremely collaborative and many resources exist to aid the new user. The first is an entire book, *Just-In-Time Teaching: Blending Active Learning with Web Technology*[9]. This reference discusses the different implementations used, theory behind the technique, and has numerous examples that can be used.

Several different web sites are also being developed that are extremely useful to the JiTT adopter. An overview of the topic can be found at www.jitt.org. This site provides background material on JiTT, presents a number of examples from a variety of disciplines (as well as some representative answers), and lists current JiTT adopters from across the country. There is also a listing of available JiTT Workshops that are offered throughout the year [this page needs to be updated if there are other workshops being planned].

The JiTT Digital Library, JiTTDL, is being developed with support from an NSF grant. By accumulating resources from JiTT users, this library will help JiTT practitioners do the following: create web material such as WarmUps and Puzzles, anticipate student responses, plan the lesson and classroom activities, deal with technology issues, and assess the effectiveness of JiTT. The website is currently under development, but progress can be tracked at www.jittdl.org.

A tutorial on creating your web contact can be found at www.jittweb.org, and other resources will be posted on the web pages noted above. This will greatly reduce the workload for a new instructor just beginning to utilize JiTT. Many JiTT adopters are willing to "loan out" their web questions, provided they are given appropriate credit for their intellectual property.

Assessment

While there is a large community of practitioners of JiTT, there is a paucity of assessment information on using the technique. A recent NSF Small Grant for Exploratory Research (SGER) was recently given to the Air Force Academy to try to evolve the JiTT Community of Practice into a Community of Research. We are currently collecting information on what different instructors have attempted using JiTT, and what assessment data they have collected. As this information is collected, it will help to provide insight into further research avenues for assessing the effectiveness of the technique.

There are some reports on the assessment of JiTT. An excellent review of the use of JiTT at Indiana University Purdue University Indianapolis (IUPUI) was presented at the 2003 ASEE Conference[(3)]. They have looked at effects on student retention, student subjective attitudes, and on improved learning. First semester introductory mechanics attrition rates (which included grades below C-) improved by nearly 20%, with a rate of appromately half that in an introductory electricity and magnetism course. Over 85% of students answered yes to: do you feel that the WarmUp assignments and other web assignments caused you to stay "caught up" on class material, and 88% agreed that WarmUps are a good idea.

Another excellent article from IUPUI examined the use of JiTT in Biology.[(10)] Assessment results included: trained classroom observers reported greater student-faculty interaction in JiTT classes; 87% of students rated Warm Ups responses "very useful to learning the fine points"; retention rates improved; self-reported class preparation was higher in JiTT courses; and Warm Ups resulted in less "cramming" when preparing for exams. Some of the most interesting results involved the cognitive gains shown in the course. A 20 question multiple choice test that measures conceptual understanding in Biology was given to students before and after the course. A normalized gain can be computed using these results, and increases were found for the following cases: questions on concepts that were discussed in class without additional classroom activities showed a 15% gain; questions reinforces by homework problems showed a 21% gain; questions reinforced by either Warm Up question or cooperative learning activity showed a 52% gain; and questions reinforced by both Warm Ups and cooperative learning activities showed a 60% gain.

Conclusions

Just-in-Time Teaching is an innovative new teaching strategy that combines the technological advances of web based learning with highly effective lecture techniques of interaction and engagement. While JiTT is commonly used in the physics community, there has been little evidence of its use in the engineering classroom. Although the authors are unaware of any use of JiTT in the engineering mechanics community, it seems that the technique could be easily applied in this discipline. We have provided the groundwork for mechanics instructors to utilize this new pedagogical approach, and listed resources to aid in the implementation of JiTT. It is hoped that the engineering mechanics community can benefit from this approach as much as the physics education community has.

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Dr. Gregor M. Novak is Distinguished Scholar in Residence and Professor Emeritus in the Department of Physics at Indiana University Purdue University Indianapolis (IUPUI.). His primary scholarly interest is the application of multimedia technology to improve undergraduate physics teaching. Over his tenure on the faculty at IUPUI and at USAFA, Dr. Novak has been at the heart of numerous successful innovations for undergraduate physics teaching and learning. He has extensive leadership experience with faculty workshops having given over a hundred and fifty invited workshops and presentations on technology in the physics classroom over the past 10 years. He is the co-author of the book: Just-in-Time Teaching: Blending Active Learning with Web Pedagogy, Prentice Hall (1999.) Dr. Novak has received several teaching awards, including the 1998 Chancellor's Award for Excellence in Teaching at IUPUI. Just-in-Time-Teaching (JiTT) introduces a blend of the state-of-the-art multimedia technologies exemplified by the World Wide Web and active learning pedagogy into the traditional introductory physics curriculum. In this approach, outside-the-classroom technology-based assignments are given equal weight with the in-class, active learner collaborative activities. Although the JITT project is only six semesters old, there is already considerable evidence that its approach improves student attitudes, retention, and performance.

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