
Just-in-Time Teaching: Technology Transforming Learning: A Status Report

Evelyn T. Patterson, United States Air Force Academy, Colorado Springs, CO

Just-in-Time Teaching (JiTT) is a pedagogical strategy that leverages the power and convenience of the web technology to improve student learning, skill building, and attitudes. JiTT courses build feedback loops between pre-class preparations by students and faculty and in-class activities that meet the students where they are to help them move forward.

JiTT in a Nutshell

The essence of JiTT is remarkably simple, but the dividends can be profound. The basic idea is this: Before class, students complete short but carefully constructed web-based assignments related to the upcoming class topics. These assignments, often called "WarmUps" or "Preflights," generally have the students read relevant textbook sections and reflect and draw on prior knowledge to answer the questions. The students submit their answers electronically, often just hours before class. Before class, the faculty member reads the student submissions, looking for students' level of understanding, troublesome areas, and common approaches and probing for any required underlying skills and/or background. Armed with these insights, the faculty member tailors the classroom session activities "just-in-time" to make the best use of the classroom face-to-face time. In a JiTT course, discussion of and activities based on the WarmUp questions and the student responses to them are central to the classroom time. Often, (anonymous) excerpts of student responses are presented in class and used as discussion points or as centerpieces of class activities. During these discussions and the related activities, essentially all of the day's content is addressed. Each classroom session serves as the starting point for the WarmUp assignment for the subsequent class. Thus, at the heart of JiTT are feedback loops

between the outside-of-class preparation and the face-to-face classroom session that has been constructed from the students' knowledge and understanding. To the students, the entire lesson has sprung from what they have contributed. To the faculty member, the content is likely very similar to what it would have been without JiTT, but the "face is fresh" because the content is expressed in the students' words.

Recognition and Growth of JiTT

First developed in 1996 by collaborating faculty at Indiana University–Purdue University Indianapolis (IUPUI) and the U.S. Air Force Academy, JiTT has enjoyed a rapid spread across disciplines, institution types, and levels of courses. As of mid-2004, there are ~300 faculty in about 25 different disciplines at ~100 institutions across the U.S. and in Canada, Europe, and Israel who have adopted and adapted JiTT for their courses. (Please visit the JiTT website, www.jitt.org, for a partial listing of JiTT adopters/adapters.) Because there has been no formal mechanism for JiTT adoption, there are certainly many other unknown adopters; therefore, the JiTT adopter/adapters statistics or listings are unrepresented.

A very exciting recent development that will lead into the next phase of JiTT growth is the newly launched JiTT Digital Library (JiTTDL) (www.jittdl.org), part of the NSF-funded National Science Digital Library (www.nsd.org) initiative. This \$850,000 three-year project will provide a virtual meeting place for the growing JiTT community and will offer access to and organization of a wide variety of JiTT-related resources. More details about the JiTTDL appear in a later section of this chapter.

JiTT has garnered considerable attention and recognition in various pedagogical circles and communities. Recent citations include Harvard's Project Galileo site, *Science* magazine, *Teaching with Technology*, *Teach* magazine, *Converge* magazine, the Report of the NSF Workshop on Improving Undergraduate Education in the Mathematical and Physical Sciences through the Use of Technology, Tomorrow's Professor ListServ, and the Strategic Programs for Innovation in Undergraduate Physics (SPIN-UP) project report. Also, in 2003, Project Kaleidoscope (PKAL, www.pkal.org) sent a small delegation of educators to China, where the educators enthusiastically received the JiTT presentation.

JiTT has also received considerable funding for implementation and dissemination; 10 faculty have been or are being supported by five NSF grants to implement JiTT in six disciplines. For more citations and for a complete listing of NSF-funded JiTT initiatives, please visit www.jitt.org.

A Closer Look at JiTT Implementation

At the heart of JiTT are the web-based WarmUp (Preflight) assignments. Carefully constructed WarmUp questions motivate students, help them make connections between their everyday life and the textbook, and prepare them for the classroom session. The student responses to these questions provide faculty with rich insight into the states of the students' minds on the topics at hand, "just-in-time" to tailor the classroom session to best meet the needs of those students.

While many factors contribute to successful JiTT implementation, the single biggest factor is probably using "good" questions in the pre-class WarmUps. Good questions typically probe conceptual understanding, are extendible, elicit a wide range of responses, and relate or connect the subject matter to the students' experiences (see, for example, Novak et al., 1999, pp. 45–49).

Consider the following WarmUp question used in an Environmental Engineering course (Cashman, 2003): In your reading of the *Scientific American* article, the authors reported on exposure to chloroform while in a steamy shower. How much (grams) chloroform do you inhale in your average shower? Based on the Occupational Safety & Health Administration's recommendations of 50 ppm over an 8-hour day/40-hour work week, is this a concern to you?

Or consider this question from an Introductory Physics

class (Novak et al., 1999, p. 50): In rewinding an audio or videotape, why does the tape wind up faster at the end than at the beginning?

Or consider this question from an Introductory Biology course offered by Kathy Marrs at IUPUI (Marrs, 2001): Why do you think chemotherapy drugs, which are given to fight cancer, cause a person's hair to fall out?

These are representative "good" WarmUp questions. They are, where possible, intentionally phrased in everyday, ordinary vocabulary, rather than with technical jargon or terminology. They are questions that an educated person—but not an expert in the subject—might actually ask and as such are "authentic" questions (Wiggins, 1989). Interestingly, while these questions are wonderful for WarmUps, because they build the "real world" connection, many faculty would shy away from asking such authentic questions on course exams. They would be difficult to grade, and student performance, in the context of graded exams, would likely be disappointing.

Authentic WarmUp questions do provide inroads into the issue of the type of learning being accomplished by students. To answer these questions, students cannot use typical "plug and chug" or rote/memory kinds of "ersatz learning" skills (McClymer and Knoles, 1992). Seeing student responses to questions such as these allows faculty members to explicitly address the learning processes and to encourage genuine learning without penalizing the students.

More than WarmUps

While the most important item in the JiTT suite is the WarmUp (Preflight) assignment, there are other components in a "full implementation" of JiTT. "Puzzles" are post-instruction web assignments used for closure and typically require integration of multiple concepts. "GoodFor" web essays provide enrichment materials and offer answers to the popular "What is [physics, biology, etc.] good for?" question often raised by students. A "ThisWeek" website provides weekly updates on course goings-on, points out relevant news items, and builds the sense of community among the students and faculty. The JiTT book (Novak et al., 1999) and website provide more details on these items.

Web-based post-instruction homework assignments represent a newer area of development within the JiTT initiative. If the WarmUps "prime the pump," the post-instruction

components must help the students both develop skills (such as problem-solving processes) and master content. Education research indicates that the processes or "thinking frames" (Perkins, 1986) must be explicitly taught and practiced if they are to be internalized and learned, so these post-instruction assignments under development attempt to explicitly teach both problem-solving processes and strategies as well as physics content (Patterson and Novak, 2003).

Keys to Successful Implementation

Across the diverse JiTT community, there are many intriguing variants of JiTT implementation. Exactly what transpires during the classroom session depends on the classroom facilities, class size, students, faculty member, etc. The one essential common feature is that the feedback loop not be broken. In this spirit, reading quizzes at the start of class isn't JiTT and neither is "one-minute papers" completed by students at the end of class.

Collective JiTT community wisdom suggests a few important keys to success:

- Explain about JiTT at the start of the course. Taking time to explain to students what JiTT is and how it will be implemented starts to develop the notion of the class and faculty member as a community and helps students "buy in" to the idea of preparing for class.
- Construct WarmUp questions carefully. Good WarmUp questions make all the difference in how well JiTT works for a given course. Beginning with clear lesson, course, program, and institution goals and objectives in mind provides the framework or scaffolding on which to construct the specific questions. Building on the work of others, as will be facilitated by the JiTTDL, makes this task easier.
- Make the important distinction to the students between a "good" response and a "correct" response. A "correct" response offers the "right" answer to the question posed. A "good" response provides rich fodder for classroom discussion and activities. It is therefore entirely possible that the "best" responses are articulate, well-reasoned "wrong" answers based on common misconceptions or points of view that are not correct, as these sorts of responses are perfect for bringing to the classroom. For example, if the question is, "How high will the ball go?" a "correct" response that actually isn't "good" might be

"3.5 meters." One cannot surmise the underlying thought process from reading the response, and the response doesn't encourage much discussion. However, a "good" response might be, "I cannot figure out how high the ball will go. I know it has something to do with knowing how fast the ball is thrown initially, but since it is thrown at an angle, I'm not sure what to do to figure out just its height."

- Use the WarmUp responses as the seeds for (essentially) the whole classroom session. This facilitates active learning. Avoid starting out class by going over the "correct" answers to the WarmUps quickly so that the class can then move on to the "real" lesson.
- Don't "grade" the WarmUp responses based on correctness. WarmUps are intended to "prime the pump" and to allow the students to explain their varying states of knowledge and understanding. Awarding credit based on "correctness" sends a confusing message to the students. Awarding credit based on other criteria, such as level of effort or completeness, encourages students to offer their own answers and, importantly, essentially eliminates their motivation to search for or share the answers to the WarmUp questions.
- Don't break the feedback loop between out-of-class work and in-class activities. If the feedback loop breaks, the students lose their incentive to prepare for class and put forth honest efforts to articulate what they do and do not understand.

Growing the JiTT Community: The JiTTDL

While the JiTT pedagogy has thus far spread via word of mouth, faculty development workshops, and other such vehicles, JiTTDL promises to address many needs that have to date been met in piecemeal fashion.

A faculty member interested in using JiTT faces a series of implementation tasks. JiTTDL will help with these tasks in the following ways:

- Creating web material. The library will contain many examples of existing materials actually used to implement JiTT.
- Anticipating student responses. Although the faculty member's lesson will be based on his or her actual student responses, the library data will provide some insight into what to expect.

- Planning the lesson—the classroom activity. Perusing the student responses and accompanying classroom notes from the collection will suggest a rough outline of the use of classroom time. Actual responses will build on that framework.
- Keeping up with grounding materials. Scholarly investigation of teaching and learning validates good practices and suggests improvements.
- Dealing with technology issues. Technology issues are a common hurdle to JiTT implementation. JiTTDL will provide practical suggestions and services, e.g., CGI (Common Gateway Interface) scripts and hosting on the JiTTDL server.
- Dealing with assessment issues. This will be a particularly important service to faculty who do not have on-campus access to assessment professionals.

In addition, JiTTDL will provide a forum for and encourage the exchange of ideas, tips, and experiences to enrich and broaden the experiences of the entire JiTT community. Please visit www.jittdl.org often to keep abreast of the latest JiTTDL developments.

Why JiTT Works

The spread of JiTT across disciplines, institution types, and levels of courses is testimony to its broad applicability, appeal, and effectiveness.

An ever-growing body of general and discipline-specific education research suggests that JiTT should be an effective pedagogical strategy and offers underlying reasons why. For example, Alexander Astin's landmark 30-year study of the critical factors affecting success in undergraduate education (Astin, 1993) lists the top three factors as student-student interaction, student-faculty interaction, and time on task. JiTT explicitly addresses and serves to increase each of these factors. Another classic reference (Chickering and Gamson, 1987) also distilled findings from decades of research on the undergraduate experience and offers the following seven principles for good practice:

1. Encourage contact between students and faculty.
2. Develop reciprocity and cooperation among students.
3. Encourage active learning.
4. Give prompt feedback.
5. Emphasize time on task.
6. Communicate high expectations.
7. Respect diverse talents and ways of learning.

Reflecting on JiTT and its implementation in light of these principles, one can see why it is effective across such a diverse community.

Not only can education research validate JiTT as a pedagogical strategy, but cognitive research, such as that included in the popular book *How People Learn: Brain, Mind, Experience, and School* (Bransford et al., 2000), can explain the limitations associated with certain approaches, suggest steps to accomplish specific learning goals, and provide an overarching framework to apply to the learning process. For example, learners generally do not immediately take processes and strategies first learned in one specific context and apply them correctly to new contexts—a process known as "transfer." The repeated feedback loops associated with JiTT methodology can help with transfer, and cognitive research informs and improves the JiTT implementation.

Education research results can and should be used to guide the formulation and construction of JiTT questions and assignments. For example, in introductory science courses, there is a set of student background skills generally assumed to be present (Arons, 1979), such as the ability to read and interpret graphical information. Often introductory students are missing or weak in a subset of these important skills, and WarmUp questions can explicitly probe for these skills. As another example, a new two-dimensional version of Bloom's taxonomy (Anderson et al., 2001) offers a matrix of cognitive processes versus types of knowledge (e.g., factual, procedural). WarmUp questions can specifically target a cell or cells in that matrix to foster student development in those particular skills or processes.

Assessing JiTT

The confluence of mounting evidence from the JiTT community suggests that students in JiTT courses are more prepared, motivated, engaged, and responsible for their own learning than those in non-JiTT courses. As a result, the JiTT students tend to learn more and develop better attitudes toward the courses and subject matter. However, much of what JiTT seeks to foster and cultivate—such as deep and long-lasting learning connected to prior knowledge—is difficult to document and measure. Many "typical" or traditional assessment schemes including, for example, comparisons of performance on course graded events by test and control groups are often ineffective at culling out differences in

these "fuzzier" more global and more intangible characteristics and learning outcomes.

JiTT can be used to target a variety of categories of learning outcomes. In their "Teaching Goals Inventory," Angelo and Cross (1993) offer six distinct clusters of outcomes or goals:

1. Discipline-specific knowledge and skills
2. Higher-order thinking skills
3. Basic academic success skills
4. Liberal arts and academic values
5. Professional and career preparation
6. Personal growth and development

Unfortunately, many "formal" assessment activities undertaken to date by JiTT practitioners have focused primarily on the first of these six categories—discipline-specific knowledge and skills—since these are the outcomes traditionally assessed by graded student work required in undergraduate courses and therefore most easily studied. Certainly, though, many "good" WarmUp questions help promote growth and gains in the other categories.

Increasingly, approaches undertaken to assess newer pedagogies are broader, less quantitative, more qualitative, and composed of a variety of different kinds of evidence. (For a partial listing of the sorts of evidence one might collect and analyze, see, for example, the Project Kaleidoscope website in the Bibliography.)

Evaluative Research on JiTT: A Formal New Initiative

In part because of recognition of the need to develop and implement prototype schemes for assessing pedagogies such as JiTT, as of mid-2004, there is a new and distinct NSF-funded project to perform evaluative research on the effectiveness of JiTT (Hamilton, 2004). The first part of this effort will be to consolidate, organize, and analyze the available evidence on JiTT's effectiveness in a theoretically coherent manner. The project ultimately plans to bring the JiTT practitioner community into the evaluative process as participating scholars who will embed both formative and summative evaluations into their JiTT adoptions and adaptations. This will contribute a wealth of evaluative or assessment-related schemes, instruments, and data relevant to JiTT. The JiTTDL will in turn collect and organize these materials to make them available to the broader JiTT community.

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