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ENGINEERING EDUCATION IN THE AGE OF WEB 2.0

— EXPLORATIONS THROUGH iMechanica.ORG

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ABSTRACT

Web 2.0 refers to a collection of second generation web services, such as blogs, social bookmarking, wikis, podcasts, and Really Simple Syndicates (RSS) feeds. While the first generation web (Web 1.0) is about linking information available online, Web 2.0 emphasizes online collaboration and sharing among people. These new web services bring up new opportunities to innovate how we conduct research and education. We report the preliminary explorations of engineering education exploiting Web 2.0 services, through iMechanica (http://imechanica.org). Hosted at Harvard University and powered by Drupal, an open-source content management system (CMS), iMechanica provides a platform for researchers, educators and students to experiment with innovative ideas on engineering education. For example, instructors can post syllabi, lecture notes, as well as slides and videos on iMechanica. Interested learners can view and study these posts, raise questions and make comments. Quite often an active discussion produces more useful information beyond an original post, and inspires new posts and further discussions. Furthermore, one can subscribe to these discussions through RSS feeds and is notified whenever a new entry is added to the thread of discussion. The instructing and learning through iMechanica are not limited within a specific institution or a specific curriculum. Anyone in the world can join such education processes, as either an instructor or a student, or both. These preliminary explorations of engineering education in the age of Web 2.0 hold the promise to build an online life-long learning environment without boundary.

WHAT IS WEB 2.0?

The phrase "Web 2.0" first emerged from a conference brainstorm in 2004 [1]. While the phrase suggests a new version of the Web, it does not refer to a technical upgrade of World Wide Web, but rather refers to a significant change in the way of using the Web. Such a change is indicated by the wide spread use of a collection of second generation web services, such as blogs, wikis, social bookmarking, podcasts and Really Simple Syndicates (RSS) feeds. While Web 1.0 is about linking information available online, Web 2.0 emphasizes online collaboration and sharing among people. Web 1.0 features giant websites collecting massive data at the server end and competing with each other to attract eyeballs, Web 2.0 forms loose networks accessible to search engines, harnessing collective intelligence through user sharing information. To provide a background, we now briefly describe several representative Web 2.0 services as follows.

- **Wikipedia**, a multilingual, web-based, free encyclopedia project, is written collaboratively by volunteers. The vast majority of its articles can be edited by anyone with access to the Internet. Although questioned for the reliability and accuracy due to its open nature, Wikipedia has been shown to be generally as accurate as other encyclopedias. A recent study by Nature magazine [2] comparing Wikipedia to the Encyclopedia Britannica suggested a near similar level of accuracy in terms of its natural science articles.

- **Social bookmarking web service**, such as del.icio.us, allows Internet users to store, classify, share and search lists of bookmarks for Internet resource that they find useful. The lists of Internet bookmarks can be accessible to the public. Unlike

the conventional hierachical keyword categorization system, del.icio.us allows users to tag each of their bookmarks with a number of freely chosen keywords (or tags), and also provides a combined view of everyone's bookmarks with a given tag. This collective nature of social bookmarking leads to a collaborative categorization system, referred to as folksonomy (in contrast to taxonomy). Non-hierachical tagging also allows for multiple, overlapping associations in natural thinking, rather than rigid categories.

- An **RSS feed** provides a table of content links frequently updated to reflect a website's content. An interested user of the website can subscribe to the RSS feed through a feed reader to keep notified every time that website is updated. Initially used for tracking blog updates, RSS is now also being used to track a wide range of data updates, e.g., stock quotes, weather information, and photos, etc. A RSS feed aggregator allows customized subscriptions to multiple RSS feeds, providing a consolidated view of content with real time updates.

These Web 2.0 services radically change how we obtain, store, access and manage information via the Internet, and therefore bring up new opportunities to innovate how we conduct research and education. In this paper, we report the preliminary explorations of engineering education exploiting Web 2.0 services, through iMechanica.org.

iMechanica: A WEB OF MECHANICS AND MECHANICIANS

The mission of iMechanica [3] is to:

- use the Internet to enhance communication among mechanicians, and
- pave a way to evolve all knowledge of mechanics online

The Internet has provided an unprecedented opportunity for mechanicians to evolve all knowledge of mechanics online, in all its depth and splendor, from phenomena interesting to the general public, to textbooks for students, to data and tools used by practitioners, and to theories and experiments pursued by academics. iMechanica aims to be the online platform for the discipline of mechanics. iMechanica will not only preserve knowledge in mechanics, but also influence its future development. In steady state, the discipline and its online platform will co-evolve.

For any discipline of depth and breadth, the mission to evolve all its knowledge will require many individuals to participate. iMechanica will enable a large number of academics, students, and practitioners to collaborate at the forefront of research and education. For academics, iMechanica will provide ample space for them to articulate their imagination incrementally, as well as in bold brush stroke. For students, iMechanica will provide an infrastructure for them to shape their own future. For practitioners, iMechanica will provide an outlet for them to record their creative uses of mechanics. Furthermore, iMechanica will turn the traditional model of public outreach upside down, enabling K-12 teachers and students to contribute to projects that have kindled their interests in mechanics, and opening channels for experts to give feedback. iMechanica aims to enable people of all ages and of any proficiency to learn and practice mechanics.

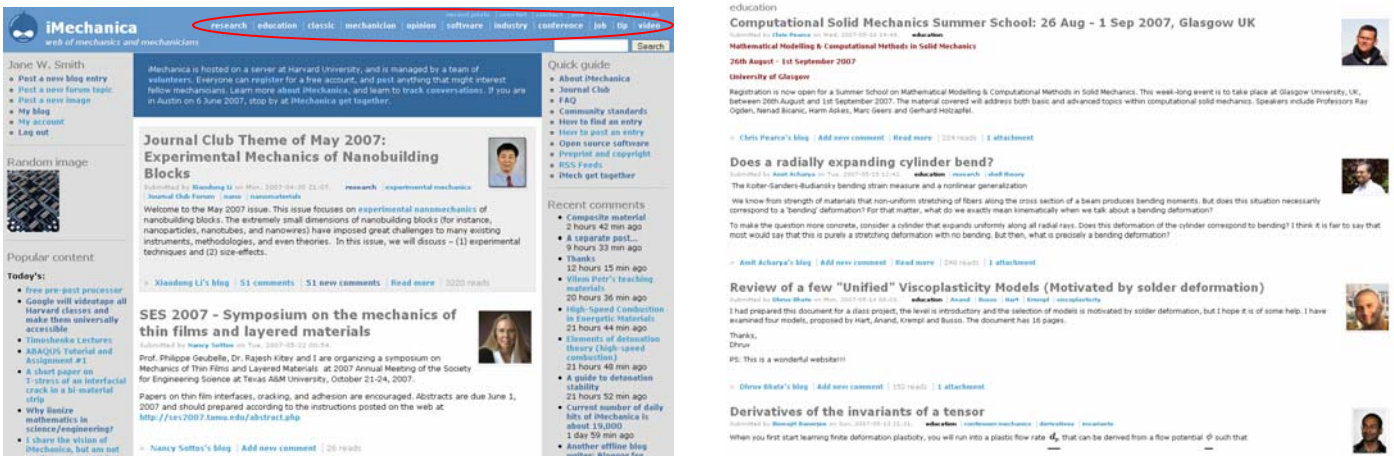
Launched on 9 September 2006, iMechanica now has 2,000+ registered users from all over the world, 1,400+ posts, 2,900+ comments, and 3,000,000+ web hits, as of May 2007. The number of average daily web hits since January 2007 is about 19,000. These numbers are steadily increasing [4, 5].

iMechanica is hosted on a server at Harvard School of Engineering and Applied Sciences, is powered by Drupal, an open-source content management system (CMS), and is maintained by a growing team of volunteers. Before iMechanica was launched, a proposal was submitted to NSF to create some sophisticated features of iMechanica. The reviewers made encouraging comments, thought that the project was very innovative but too risky. The proposal was not funded. At this moment, the cost of running iMechanica is low; we have no pressure to seek external funding. We will revisit the question of funding when needs arise.

HOW DOES iMechanica WORK?

The contents in iMechanica are contributed by its registered users. All contents are freely accessible to everyone in the world, without registration. To post new content, however, a user must register for a free account. Upon registration, the user has her own blog, and can post anything of interest to fellow mechanicians. The author of a blog entry has the option to assign the entry with multiple tags. By assigning the entry with one of the featured tags, which are listed in the header of iMechanica.org (Fig. 1 (a)), this entry is collected with other entries with the same featured tag to form a *channel*. The current channels in iMechanica are Research, Education, Classic, Mechanician, Opinion, Software, Industry, Conference, Job, Tip and Video. These channels help users navigate among the posts and locate posts of interest. The content of a channel is updated automatically whenever a user adds a blog entry to the channel and is displayed in reverse chronological order. Figure 1 (b) shows a glance of the Education channel on 22 May 2007.

While the channels aggregate posts into more general categories, iMechanica also runs a list of *forums* to facilitate the discussion on more specific topics. Among the 14 forums (as of May 2007) are Mechanics Courses Forum, Computational Mechanics Forum, and Journal Club Forum, etc. Forums provide platforms for people of common interest to exchange information and ask/answer questions. Whenever there is a growing need on a new topic for discussion, a new forum will be created.



(a) (b)

Fig. 1. (a) The web interface of iMechanica.org. Channels in the header (highlighted in the red oval) navigate a user to various collections of blog posts, e.g., research, education, classic, etc. Posts of high interest are selected and promoted from the channels to the front page (the middle section) by the managing team. The left and right side bars provide general user guide, and more importantly, real time navigation information, e.g., recent comments, recent posts, recent forum topic, today's popular content and all time popular content. (b) A glance of the blog posts by various users in the Education channel.

Users can contribute contents in a wide range of ways and formats, e.g., writing plain text, posting images, attaching word documents, pdf files, and powerpoint slides, and even embedding videos (more details in the following sections). Each entry is copyrighted by the individual user and can be used in accordance with the Creative Common License [6].

Users can comment on each others' entries, through which the interaction and discussion among users are formed. The number of total comments in iMechanica is about twice of that of total posts as of May 2007, while in 2006 these two numbers were often comparable. An actively discussed post can have more than 50 comments. The increase of comments clearly indicates the increase of the conversations among iMechanica users, which fits well the mission of iMechanica.

Recent posts and comments are displayed real time in the right sidebar of iMechanica webpage, while a list of today's and all time popular posts are displayed on the left sidebar, based on the number of times a post has been read by users. The 5th in all time popular posts has been read 8612 times in six months.

iMechanica is managed by a growing team of volunteers, serving as architects, moderators and developers. The team promotes posts of high interest to the front page (the middle section). These promoted posts often lead to active discussions among users.

ENGINEERING EDUCATION IN THE AGE OF WEB 2.0

iMechanica provides a platform for researchers, educators and students to experiment innovative ideas on engineering education. In this section, we summarize some of these explorative efforts, enabled by the Web 2.0 services available in iMechanica.org.

Interactive course webpage

The Internet has already made significant change in how we conduct engineering education. More and more lecturers set up course website to post syllabi, lecture notes and supporting materials online, instead of distributing hardcopies in class. Commercial software such as Blackboard provides templates to further simplify the process of course website setup. Such Web 1.0 course websites facilitate the distribution and maintenance of course content to some extent, but still suffer from some critical limitations. A Web 1.0 course website is *static*. The lecturer posts and the students download. This is a one-way information delivery between the lecturer and the students, no interactive communication enabled through the website. Some Blackboard-type course website offers the discussion board function, but such websites are only accessible to a small number of students enrolled in the course and often need to be reset each semester thus no discussion can be accumulated over the time. Interactive communication between the lecturer and the students, as well as among the students in the class plays vital role in an effective instructing and learning process. Such interactions can be achieved within the classroom, but not readily available through Web 1.0 course websites.

The abovementioned limitations can be easily overcome by exploiting Web 2.0 services. The following is one of the examples that have been demonstrated in iMechanica.

Take a fracture mechanics course offered in Spring 2007 as an example. The course was offered at two campuses, Harvard University and University of Nebraska. The Harvard class consisted of students from both Harvard University and

MIT. Two lecturers gave lectures at Harvard, which were transmitted to the Nebraska campus. To facilitate the interaction among the students in three campuses, a course website was set up in iMechanica.org in the following way:

A blog entry was posted in one of the lecturer's blog in iMechanica to serve as the main course webpage (Fig. 2). Such a webpage included course logistics and a list of links to individual lectures, homework sets, extra notes and reading materials. Lecture notes and homework sets were then posted as individual blog entries in the lecturers' blogs as the course proceeded.

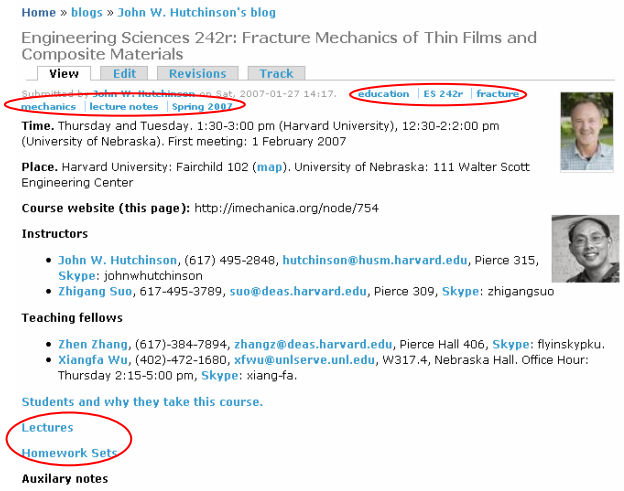


Fig. 2. The main course webpage is built through a post in one of the lecturers' blog. The post is tagged by education, ES 242r, fracture mechanics, lecture notes and Spring 2007. These tags can be used to locate course contents. The lecture notes, homework sets, as well as auxiliary notes can be reached via the hyperlinks in this webpage.

All course contents are open to public. Students enrolled in this course, as well as any other interested learners can view, download and study the course contents. Since all blog entries allow comments, learners can raise questions on any individual lecture notes or homework sets. Such questions can be answered by the lecturers, another student, or any experienced iMechanica users. This way, the interactive discussion extends beyond the lecturers and the enrolled students to any pair of educator and learner.

All course-related blog entries were properly tagged (Fig. 2). These tags were used to define a unique web link. This web link aggregates all entries related to this course in a single webpage, so that locating course contents from numerous entries in iMechanica becomes easy.

The course contents keep evolving during and after the semester. The *dynamic* interactions between educators and learners of this course will be accumulated and available to any future educators and learners. All course contents, including the main webpage, individual lectures, or the aggregated single course webpage, have their unique RSS feeds. Learners can subscribe to these RSS feed, then keep alerted of any new content added to the course. The comments can also be subscribed through a unique RSS feed. This way, educators and learners can also stay current with any new discussions in the course.

The web setup of the above course in iMechanica is as easy as posting a series of blog entries, and posting a blog entry and uploading course contents in iMechanica are just like writing an email message with attachments. No hassle to modify the webpage in html format and to access server end to upload course files, typical actions necessary to set up and maintain a Web 1.0 course website. The setup of the above course in iMechanica can be generalized and adapted to many other engineering courses. With a much lower technical barrier to set up but much more powerful functions, Web 2.0 course websites show great potential to impact future engineering education.

Curriculum comparison and consolidation

Some fundamental engineering courses (e.g, solid mechanics) are taught at almost every engineering school. While the course topic is the same, syllabi, textbooks, lecture notes, homework and background of students often vary at different universities. The comparison of curriculum among different universities will be helpful in consolidating education resources and improving learning efficiency. The success of such a comparison largely depends on the numbers of participants and how easy the interactions among them can be carried out. A traditional survey through paper media or even through email is feasible but far from efficient due to lack of interactions among participants.

iMechanica can serve as an online platform to conduct such a comparison in a much more effective way. A comparison of course notes of solid mechanics is currently under discussion in iMechanica [7]. So far, lecturers of such a course at six universities, i.e., Harvard, University of Huston, University of California at Berkeley, University of Texas at Austin, University of Wyoming and Columbia University, have involved in the discussion. We expect more lecturers of solid mechanics to participate this valuable discussion. The managing team of iMechanica has also been experimenting wikiMechanica, a wikipedia-type website that allows coordinated writing. A major function of this future project is to consolidate various education resources into a unified place accessible to general public.

Public outreach in the age of Web 2.0

Public outreach is one of the essential components of the educational activities in research institutions and makes vital contribution to K-12 science education. Traditional models of public outreach include giving public lectures, visiting K-12 institutions, organizing workshops/summer schools for K-12 students and teachers, and participating science fairs. Such activities largely rely on individual scientific researchers

reaching out for K-12 teachers and students and are often limited by the schedule and budget of both parties. In recent years many institutions start to develop web-based outreach projects, providing general science information, interactive online games for K-12 students, and teacher's kits to facilitate integration of science content into the classroom. These efforts improve the accessibility of scientific information to K-12 institution, but suffer from the lack of person-to-person communication between scientists and K-12 students. In both traditional activities and available web-based projects of public outreach, the information flow is one-way, that is, only from scientists to K-12 students and teachers. Similar to teaching in the classroom, successful public outreach essentially relies on the interactive communication between both parties.

An online platform like iMechanica allows us to redefine public outreach model in the age of Web 2.0. The traditional public outreach model can be turned upside down. A new model through iMechanica can be conducted in the following way. K-12 teachers and students can contribute to scientific projects that have kindled their interests in mechanics. They can then post the detail design and outcome of their projects in a designated channel in iMechanica. Scientific researchers can provide their feedback by leaving comments. K-12 teachers and students can then echo back, forming interactive communication. Meanwhile, scientific researchers can also post web-based educational projects in such a channel. Interested K-12 teachers and students can respond, question, and get inspired for potential future projects.

The major aim of public outreach is to promote public awareness and stimulate student interest in science and engineering. A key factor for the effectiveness of public outreach is how vivid and inspiring the demonstrations are. For the online outreach activities, video demonstrations become a natural solution. iMechanica allows users to embed videos in their posts in a convenient way [8], enabled by another available Web 2.0 service YouTube. A video channel has been opened in iMechanica to integrate mechanics-related videos for scientific research and public outreach. Figure 3 shows an example in the video channel. This post includes an educational video clip designed to explain an emerging technology — flexible macroelectronics, and related mechanics challenges for middle school students.

The advantages of the Web 2.0 public outreach model over the traditional one include: It opens up two-way interactive communication between the scientists and the K-12 teachers and students, allowing both parties to reach out to each other. It greatly broadens the impact of the outreach activities. Such activities are open to any interested audience with Internet access. Any interested scientific researchers can volunteer to offer their advice for student projects. The students will benefit much more from the collective wisdom than from the traditional one-to-one communication. The free service in iMechanica also significantly reduces the cost of public outreach.

Fig. 3. A blog entry with an embedded educational video designed for middle school students.

K-12, college, graduate school and beyond

Engineering education is a life-long process. K-12 students are inspired by the intriguing scientific phenomena either in the classroom or through outreach activities. College engineering students are educated through fundamental engineering courses. Engineering graduate students obtain advanced training to conduct scientific research. The engineering education just does not end there. Accumulated over millennia, the knowledge base of engineering science is huge. The ever differentiation of various branches of engineering science makes impossible for a single person to be an expert of all disciplines. Obvious evidence is the increasing number of collaborating authors of scientific publications, rather than the typical sole author publications in early days. Solving engineering problems and conducting scientific research often involve learning new knowledge. In this sense, anyone can be an educator in the fields of her expertise, and can also be a student in otherwise fields of her interest.

The engineering education beyond graduate school often takes the form of self learning, e.g., reading scientific publications, joining journal clubs, and attending workshops and conferences. The interactions with each other can be in the forms of in-person discussion, telecommunication, and more often nowadays, email exchange. These typical forms have certain limitations. The scope of people one can interact with is often limited to close colleagues and friends. Attending workshops and conferences allows interactions at a broader

scale, but only within limited period of time and is quite often time- and budget-constrained.

The above limitations can be overcome by a Web 2.0 education platform such as iMechanica. As already delineated in the previous sections, iMechanica brings mechanicians of common interests together and serves as a platform for discussions and interactions. Posts deliver ideas and concepts, comments raise questions and arguments. Authors response, readers echo. Quite often an active discussion produces more fruitful information beyond the original post, and inspires new posts and further discussions.

A successful demonstration of iMechanica being an education platform is the Journal Club [9]. Inaugurated in January 2007, the Journal Club aims to facilitate the discussion at the frontier of mechanics and its applications. The Themes of the Month are solicited among iMechanica users. At the beginning of a month, the Discussion Leader of the Month will post the Theme of the Month. The Theme will stay as the top entry for the month in the front page of iMechanica (shown in Fig. 1 (a) is the theme of May, experimental mechanics of nanobuilding blocks). The post consists of an introduction to the Theme, and links to 3 papers. The Theme of the Month and the papers are a means to an end: facilitating discussions at the forefront of mechanics among mechanicians. All iMechanica users can comment on these papers. In the comment on a paper, a user may discuss the ideas in the paper and their relations to other papers, especially the papers that he knows the best: his own papers. He can also relate the paper to a broader context. This way, the readers of the Journal Club can discuss and interact, eventually enrich their knowledge of the fundamentals in mechanics, as well as of cutting edge research. Journal Club turns out to be the most popular activity in iMechanica. For example, every past theme had 2000+ reads. For example, as of 24 May 2007, the May theme has had 3400+ readership and 53 comments. The breadth of the audience and the depth of discussion surpass far more those of the traditional form of journal club.

Such a learning process through iMechanica Journal Club can be also combined with traditional education activities. For example, one of the authors of this paper led the Journal Club theme in March: Mechanics of flexible electronics. Meanwhile he was teaching a new course on flexible electronics at University of Maryland. The students in the class were asked to conduct a literature research related to the March Journal Club theme and post their comments in iMechanica. This way, the students were exposed to the frontier of mechanics and its application, and interacted with a much broader audience through discussions at the frontier in iMechanica, a valuable experience for these future researchers.

iMechanica WAY

The idea to initiate the Journal Club came from Pradeep Sharma, a user of iMechanica. His post [10] attracted the attention of other users, whose comments refined his proposal, and guided the formation of the Journal Club. The experience of starting the Journal Club has become an example of "iMechanica Way": let users suggest and refine approaches to complex tasks and issues openly and for a period time. Consensus is reached and labors are divided. A more recent example is a thread of discussion on community standards, initiated by John Dolbow [11], to resolve issues concerning uncivil posts in iMechanica. Another example is a thread, initiated by Michelle Oyen [12], on integrating biomechanics and applied mechanics.

CONCLUDING REMARKS

The Web 2.0-enabled iMechanica provides a platform for researchers, educators and students to experiment innovative ideas on engineering education. Some explorative efforts range from setting up interactive course webpage, comparing and consolidating similar engineering curriculum, redefining public outreach into a two-way communication, and enabling mechanics education beyond classroom through platforms such as journal club forum. The discussions among iMechanica users in all these activities can be subscribed to through RSS feeds so that the subscribers can be notified real time with the latest update of the discussions. The service of iMechanica is free and open to public. Therefore, the instructing and learning through iMechanica are not limited within a specific institution or a specific curriculum. Anyone in the world can join such online education processes, as either an instructor or a student, or both.

iMechanica even brings users together offline. iMechanica users get to know each other through online interaction, then meet over lunch, continue their discussions. iMechanica users have planned a get-together during the 2007 ASME Applied Mechanics and Materials Conference [13], making a seamless integration between real life and online virtual interactions.

The preliminary explorations of engineering education in the age of Web 2.0 through iMechanica.org hold the promise to build an online life-long learning environment without boundary. We are still at the beginning of a learning process, through academic reading [14], as well as practicing on iMechanica. Please join us at iMechanica.org and explore.

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