A new era of learning

Professors Timothy Stelzer, Gary Gladding and Mats Selen are innovators in multimedia learning. They explain how they are enhancing teaching in physics and discuss why it is important to continually evaluate pedagogical methods.

What inspired you to revise existing educational technologies and methods?

TS: At the University of Illinois, we have the privilege of teaching some of the best undergraduate students in the country. However, this great opportunity brings significant challenges. Namely, we face real-world constraints due to the large number of students we teach within the limited class time and space that we have. Trying to improve the educational experience of our students, given these challenges, has driven our development of new educational technologies and methods.

For example, we first developed I-clicker™ based on our own need for an effective way to implement peer instruction in our large lectures. We realised it was important to develop a student response system that was effective and efficient, but also absolutely unobtrusive, so that students could concentrate on discussing and answering questions without focusing on the technology needed to submit answers. The next step we made to improve the in-class experience of our students was to create multimedia pre-lectures to enable students to come to the lecture better prepared to engage in meaningful peer instruction.

GT: What role did your background and experience shape your ideas of how education can be improved?

How has your background and experience shaped your ideas of how education can be improved?

MS: I had some great teachers and role models that inspired me when I was a student. They were all very engaging and innovative and involved me with the material, which made me believe this was a good pedagogical approach long before I knew that education research said the same thing. I have always loved technology, and tinkering and playing with gadgets. The idea of designing technology that can actually improve education is very attractive to me – I can have fun and do something useful at the same time!

Can you elaborate on the concept of multimedia learning and its benefits?

G6: Research has shown that when properly implemented, content can be conveyed most efficiently using multimedia modules. By requiring our students to view multimedia pre-lectures that deliver the fundamental content usually covered in an in-person lecture, we are free to devote this precious in-person time to helping students apply that content to different situations through strategies like peer instruction. Therefore, rather than giving a traditional lecture for 50 minutes, we now briefly review the key elements, and then spend the bulk of the time discussing how these ideas apply to particular situations.

Is evaluation of current educational methods necessary, even if they have been seemingly successful for many years?

TS: Yes. Technology is changing who we teach, what students need to learn and, therefore, how we teach. Just as students need feedback on how well they are learning so they can continue to improve, faculty need feedback on the efficacy of their teaching.

MS: Evaluation is always important as content and pedagogies change. It is also important to ensure the correct parameters are being evaluated. For example, we ultimately want our students (i.e. future scientists and citizens) to learn the skills needed to address existing problems and scenarios and understand the scientific processes used when others solve such problems. This involves reasoning skills and habits of mind beyond the simple memorisation and pattern matching that many students use to succeed in their science classes.

Why is there a critical need for improving how physics, in particular, is taught? What role can multimedia play in this?

G6: Physics has an intrinsically high cognitive load, which makes it challenging to learn, and also a favourite topic for educational research and reform. Research has shown that providing both auditory and visual representations that mutually reinforce each other can effectively reduce cognitive load for students. Therefore, multimedia is an efficient way for people to construct their understanding of complex ideas.

MS: We live in a world that is increasingly more dependent on science and technology, yet only a small fraction of people really understand how any of this technology actually works (and this fraction is shrinking as technology advances). Basic education in STEM is a key part of shaping productive citizens.

PROFESSORS TIMOTHY STELZER, GARY GLADDING & MATS SELEN
IN THE LAST decade, multimedia has emerged as an innovative teaching and learning strategy, enhancing the ability of students to engage with and absorb new and complex information. Research on multimedia learning has corroborated the efficacy of multimedia presentations; use of words and pictures rather than words alone, and animation and narration rather than animation and on-screen text, for example, have been found to improve information retention and reduce learning time. These findings have prompted academia to reconsider traditional methods of teaching and information communication, employing both auditory and visual channels to enhance student learning.

For example, incorporating multimedia learning activities in the form of pre-lectures allows students to come to lectures better prepared to benefit from interactive teaching methods. Two examples of effective methods that have been adopted in institutions across the globe are peer instruction and just-in-time teaching. Peer instruction is a flipped learning approach in which students learn content online at home via videos or other audio-visual tools and then spend class time with teachers to resolve misconceptions and overcome challenges with the topics. Similarly, just-in-time teaching links activities conducted in and outside of the classroom. For example, students submit answers to web-based questions ahead of class, which enables the instructor to develop targeted learning exercises for subsequent use.

EXCELLENCE IN PHYSICS EDUCATION
The success of these pedagogical approaches has been attributed to their responsiveness to students’ needs; lessons are adjusted to maximise usefulness and productivity. Professors Timothy Stelzer, Mats Selen and Gary Gladding from the University of Illinois at Urbana-Champaign, USA, are building on these existing techniques to innovate new methods for further refining physics teaching strategies by developing new technologies and multimedia learning tools. “The traditional method of measuring student performance using physics and mathematics questions is much easier than measuring their attitudes and thought processes; however, this often means that assessment is not well aligned with the actual learning goals,” Selen states. “Multimedia learning tools simply seemed like a way of exploiting technology to better match educational content to the way that humans learn most efficiently.”

Responding to a dearth of existing research at the university level examining whether students learn basic physics content better from multimedia presentations than reading textbooks, the team set out to ascertain conclusively the impact of expanding physics beyond the textbook, and thereby determine how best to spend lecture time.

To do this, the researchers developed and tested the use of web-based multimedia learning modules (MLMs) for introductory physics, with the goal of discovering the efficacy of these tools before devoting effort to designing and implementing multimedia presentations for large enrolment courses.

LEARNING NATURALLY
Following an initial literature review to discover what the scientific community knows about how people learn, and based on cognitive principles, the researchers developed pilot MLMs covering four topics that every introductory physics student must understand – Coulomb’s Law, electric fields, electric flux and Gauss’ Law. Each of the modules covered one lecture’s worth of course content and was split into 10 scenes implemented as a Flash movie consisting of dynamic animations and an audio narration, with embedded assessments.

This MLM mode of teaching was contrasted with a textbook mode, in which the researchers used verbatim material from a traditional textbook. Student volunteers received either two MLM or textbook sessions lasting 90 minutes that were distributed over two days in the same week. This was followed by a post-session assessment. The students were also tested two weeks later to measure retention rates. The findings of this initial work supported the team’s theory that undergraduate learning from a typical modern introductory textbook
ENHANCING STUDENT LEARNING THROUGH MULTIMEDIA LEARNING MODULES

OBJECTIVES
• To refine teaching strategies to enhance the learning experience of university-level physics students
• To develop and test multimedia learning tools to improve student learning

FUNDING
National Science Foundation grant DUE-0817185

CONTACT
Dr Timothy Stelzer
Professor of Physics
Department of Physics
University of Illinois at Urbana-Champaign
1110 West Green Street
Urbana, Illinois 61801-3080
USA
T +1 217 265 0738
E tstelzer@illinois.edu
www.physics.illinois.edu

TIM STELZER is Associate Professor of Physics and distinguished teacher-scholar at the University of Illinois. He received a BS in Physics from St Johns University in 1988 and a PhD in Theoretical Particle Physics from the University of Wisconsin at Madison in 1993. Alongside Professors Mats Selen and Gary Gladding, he is a co-inventor of the I-clicker™ personal response system and is co-author of the ‘smartPhysics’ learning system.

MATS SELEN has a BS and MSc in Physics from the University of Guelph. He earned his PhD in 1989 from Princeton University. He is currently Associate Head for Undergraduate Programs at University of Illinois.

GARY GLADDING received his PhD in Physics from Harvard in 1971. He is a high energy experimentalist and has led the faculty group responsible for the revision of the introductory physics curriculum at University of Illinois.

fared poorly when compared with learning from well-researched multimedia modules. “The results of our study were quite dramatic; we saw a full letter grade improvement,” the researchers enthuse. “These findings are very consistent with the results we saw in the literature. Therefore, we published our results, and then moved on to create a complete set of pre-lectures for introductory physics.”

Excitingly, despite the researchers’ focus on physics, the premise of their work is highly transferable. They highlight: “Multimedia pre-lectures are designed to take advantage of our natural way of learning”.

NEW ENTHUSIASM
In its second phase of research, the professors implemented the MLMs in a classroom setting as pre-lectures, and assessed their efficacy in three key areas: preparedness for lecture, performance on exams, and perceptions of the courses and of physics. In regards to their goal to discover if students were prepared to learn more in a lecture if they had been exposed to the material previously: “We saw significant results. Students came to class better prepared, found it significantly easier to learn the material, and learned considerably more during lectures,” they reveal. Although the statistically significant improvement on homework and exams was encouraging, the most exciting results came from the end-of-term anonymous survey. Prior to the teaching changes, nearly 80 per cent of students rated the class as one of the most difficult they had ever taken. However, after the changes that number dropped to 40 per cent, illustrating the dramatic impact this pedagogy can have on student learning. Similar improvements were seen in attitude toward physics and perceived value of lectures.

TECHNOLOGY WITH AN IMPACT
Alongside these studies, Stelzer, Selen and Gladding have developed technologies that complement and enhance pre-lectures. I-clicker™, an electronic polling device that allows students to quickly and anonymously respond to peer instruction questions, is now used by more than 2 million students at over 900 institutions. They are also responsible for both smartPhysics, a web-based learning environment optimised for ‘flipped classes’ utilising pre-lectures, and IOLab, a handheld wireless device with an online content delivery system that enables students to independently explore key physics concepts. “So far I-clicker™, smartPhysics and IOLab have all been quite successful,” Selen shares. “The level of success and impact of each is roughly proportional to the length of time that it has been available to the community of users.”

SPREADING THE WORD
Looking ahead, the team plans to continue expanding the availability of the novel pre-lectures, which is mainly being accomplished through a collaboration with Macmillan publishing. In addition, the researchers are collaborating with colleagues in economics who have created a complete set of pre-lectures for introductory economics, set to be released later this year. “Several other authors have also expressed interest in adding pre-lectures,” they reveal. “We expect that they will become available in most disciplines in the near future.”