Towards a Community of Practice Concerning the Use of Adaptive Tutorials in Engineering Mechanics

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***Abstract**: This paper outlines current work that seeks to address persistent challenges in Engineering Mechanics education, through the development of Adaptive Tutorials that target threshold concepts in this field. Adaptive Tutorials are interactive online modules where an Intelligent Tutoring System adapts the instruction level to learners, based on their individual performance. Following a successful pilot study at UNSW, a new ALTC project has been launched, in which a team of Engineering Mechanics educators from a range of Australian universities explore the applicability of using Adaptive Tutorials in their teaching practice. In order to achieve adoption of this innovative educational technology, a novel strategy was developed which seeks to promote educators' pedagogical ownership over the Adaptive Tutorials through a community of practice. This paper focuses on the rationale behind that strategy.*

Pedagogical Ownership over Online Educational Resources

In a vision paper Hadgraft (2007) calls for the engineering education community at large, and AaeE community in particular, to develop a coherent strategy for computer-assisted learning and assessment. Hadgraft, a proponent of project-based learning, suggests that educators should spend more time working with students on professionally relevant projects which *drive the learning*, and less time at lectures dictating basic skills. What he calls "the iPod, iBlog, iGoogle generation" need more flexible ways of learning and demonstrating engineering expertise than what chalk-and-talk instruction can offer. Projects *drive* learning because they present students with real-world problems, and seeking solutions to these problems motivates students to learn the appropriate knowledge they lack. In that sense, project-based learning is a classic example of constructivist pedagogical approaches.

Given the vast amount of online educational resources available, it should be possible to locate resources suitable to learning specific skills, and make these available to students "on demand" so that they can learn the skills they need as they arise from the project tasks. Towards that end, a recent project explored existing online learning resources in the area of Engineering Mechanics (Goldfinch and Gardner 2010). The researchers carefully evaluated freely available online resources and catalogued them into a database. The aim of this database is to encourage students to be proactive in improving the quality of their learning by assisting them to select learning resources best suited to their needs.

One inherent problem with online resources is that they are difficult to adapt to specific students or teachers' needs; pedagogical aspects of the content are tied to the worldview of the producer, and teachers who wish to use them must either accept those, or dictate a flexible usage for the context and breadth of instruction they desire. The problem is not too acute when covering topics that are fundamental to any specific disciplines, as one can argue that typically, there is little variation in the

teaching of these types of topics. But the nature of higher-education is such, that teachers are established researchers in the field and often feel they "own" the discipline's knowledge. They often want more pedagogical control over the activities they dictate to their students. The general feeling academic teachers have towards pre-existing resources is summarized in the response of one of the academics that was interviewed, on the usage of off-the-shelf educational software:

> *"Well, most of us have done it, and I think most of us use some off-the-shelf software. But what happens with it, is that inevitably it is good in some areas and not in others because it's something that was typically produced in another university for their courses, which are a little bit different and so, it is an imperfect match. Or, it is a completely commercial package which is therefore rather general, and so it is an average of what everybody wants rather than what anybody specifically needs."*

There is a great variety in the types of online resources available and there is certainly no shortage of them, however, almost invariably, they implicitly reduce the role of the teachers who use them to simply point students to them; they are rarely built in such a way that teachers can adapt them to their specific needs.

This poses a question – can online educational resources be built in such a way that teachers could adapt and refine them to better suit their specific needs? Surely some level of control must be possible, for example the ability for teachers to choose some activities over others and the ability to choose when activities are to be accessed by students. In order to answer the technical question of how to build educational resources that can be adapted, the kind of adaptation that is needed must be understood. Such a question reveals the need to contemplate the nature of the relationship between teachers and the educational technology that is available to them. One view, is to consider the role of a teacher as that of an educational action researcher (Laurillard 2008, Dick 1997). Within such an approach, the role of teachers in today's technology-saturated environment is to continuously research the best usage of educational technology for their students; to *reflect* on the pedagogical suitability of its instruction and to *adapt* it to better suit their students' needs. This approach is also rooted in Laurillard's 'Conversational Framework' (Laurillard 2002), which essentially models teaching as a step-wise conversation on two levels: the descriptive level and the task goal level. In each, the student and the teacher (or the teaching agent mediated through technology) continually adapt the descriptions and their actions on the task goal based on on-going reflection.

Such an approach can provide the appropriate functional requirements that are needed when developing online resources; it should be possible for teachers to be able to perform reflection and adaptation using it. To achieve this, tools with which adaptation can be performed (authoring, editing or customizing) must exist as well as tools for reflection and analysis.

When considering the practical implication of such a requirement, it should be noted that using any educational technology necessitates some mastery over the technology in which it is built. For example, the use of PowerPoint presentations - arguably the most prevalent computer-based educational technology used in classrooms today - necessitates computer literacy and familiarity with the PowerPoint authoring software. In a similar fashion, any computer-based resource which teachers are expected to be able to adapt (i.e. change, edit and control some element of the environment) entails learning to use yet another authoring software tool. The more complex and involved the instructional media is, the more complex the authoring software tool is. For example, some educational resources use multimedia, simulations or even artificial intelligence that intelligently adapt to students' behaviour. Enabling teacher's control over such instructional media means complex and advanced tools, but more importantly skills and expertise, which are sometimes beyond what can be assumed of teachers.

In light of the above, a distinction should be made in what is meant in letting teachers assume control over instructional media, separating the notion of technical control – the ability to dictate and change technical elements of the instruction, versus pedagogical control – the ability to dictate and change pedagogical elements of it. Although it might be impossible to assume teachers will have the technical skills required to work with the technology, for example, complex simulations, it should be assumed that they will have the pedagogical control over the instructional elements of the simulation and its

usage by their students. The term "Pedagogical Ownership" was coined by Ben-Naim et al. (2010), to describe the role of teachers in using advanced educational technology:

> *Pedagogical ownership over instructional material means that the owner understands the content, the delivery mechanism and the pedagogy underpinning it. The owner is able to deliver the content to learners, to reflect on the effectiveness of that content and to adapt it to better suit the learning needs of students. It is therefore possible to conduct educational action research with such material.*

Developers of educational technologies must strive to enable teachers to assert pedagogical ownership over resources built using it. Be it an online simulation, a wiki, a quiz or a set of lecture notes and videos on a topic; for teachers to be able to conduct educational action research using these resources in their practice. It should be possible to meaningfully reflect on the suitability of the resources to the students, gauging their reaction, its learning effect, and adapting – changing and augmenting them, or their usage – to suit specific students' needs. The following section proceeds to present how such an approach was taken in developing Adaptive Tutorials on topics in Engineering Mechanics.

Adoption of Adaptive Tutorials on Engineering Mechanics in UNSW

Since 2007, a set of 'Adaptive Tutorials' have been developed in the school of Mechanical and Manufacturing Engineering in the UNSW (Prusty, Ho and Ho 2009). Adaptive Tutorials are eLearning modules where an Intelligent Tutoring System (ITS) adapts the instruction level (difficulty, feedback and activity-sequence) to learners, based on their individual performance.

From a pedagogical point of view, Adaptive Tutorials are analogous to real world teaching laboratory activities and are similar to the concept of Tutorial Simulations as described by (Laurillard 2002). They can be described as a pragmatic hybrid between instructivist and constructivist educational theories, trying to strike a balance between guided and discovery learning. Adaptive Tutorials are typically guided, featuring a detailed explanation that leads students through the interaction, whilst offering adaptive, remedial feedback in response to learners' misconceptions. Adaptive Tutorials are also interactive, typically featuring a simulation, enabling students to investigate a phenomenon, or a relationship between parameters of a problem in a hands-on manner, thereby encouraging discovery learning.

Adaptive Tutorials exhibit three types of adaptivity:

1. students receive feedback that is adapted to their specific misconceptions
2. sub-activities (questions, tasks) can be sequenced adaptively based on students' performance
3. teachers adapt the Adaptive Tutorials themselves, based on reflection and analysis of the student's behaviour

The third level of adaptivity is what distinguishes the work on Adaptive Tutorials from other ITS research and is of relevance to this paper: the idea that the domain expert should assume pedagogical ownership over them, and be able to adapt pedagogical aspects of them, based on detailed reflection of their impact on students. The approach comes as a reaction to criticism raised in recent years about the overall impact of ITS research for mainstream education. Woolf, one of the leading researchers in the field asks:

> "Given the large potential for improving education through new technology, why aren't' thousands of effective education resources available for teachers in various disciplines? Where are the repositories of intelligent tutors?"
>
> (Woolf 2009, p:394)

The approach that was taken at UNSW was to promote pedagogical ownership of Adaptive Tutorials as a means to increase adoption by teachers. To date this endeavour resulted in the integration of over 40 Adaptive Tutorials into the syllabi of 10 major courses (each with 50–700 students), and accessed by over 3000 students a year (Ben-Naim, Marcus and Bain 2009, Velan, et al. 2009, Prusty, Ho and Ho 2009).

In order to promote pedagogical ownership, teachers play a pivotal role in the development process of Adaptive Tutorials. As mentioned before, from a pedagogical point of view Adaptive Tutorials resemble teaching laboratory activities. In fact, this analogy goes deeper, and forms the basis on which teachers are introduced into the lifecycle process of Adaptive Tutorials. The conceptual framework for developing Adaptive Tutorials is called Virtual Apparatus Framework (VAF, Ben-Naim, Marcus and Bain 2007). Its premise is that teachers should be able to develop Adaptive Tutorials in a way that is analogous to how they develop laboratory activities. In other words, they need not be concerned about building the software or understanding exactly how it works, but rather they should be able to import prefabricated "apparatus" into a learning environment, and then author lesson-plans that guide students through interaction with the apparatus. VAF's basic building blocks - Virtual Apparatus - are virtual equivalents to real-world laboratory equipment. In order to build Adaptive Tutorials in VAF, the Adaptive eLearning Platform is used. It is a software implementation of VAF that supports the life-cycle of Adaptive Tutorials.

Analysis Tools that Support Educational Action Research

Adaptive Tutorials are not "launch and forget" projects. Once deployed, teachers use an analysis tool, which creates a visual trace of student performance, (Figure 1) to scrutinise their students' interactions during the Adaptive Tutorial, and to adapt it as needed based on their students' demonstrated misconceptions. This creates a powerful educational experimentation environment where hypotheses about students' learning can be evaluated, adapted and then shared and published. Teachers thus become educational action researchers, confirming or disproving their hypotheses about the best way to help their students learn (Ben-Naim, Marcus and Bain 2009).

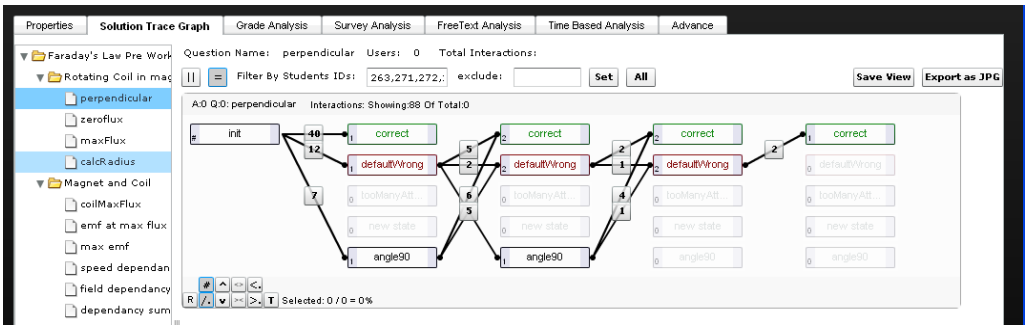

Figure 1: The Adaptive Tutorial Analyser uses A Solution Trace Graph to visually analyse students' solution-traces through the problem state-space

A Community of Practice Approach to Increase Pedagogical Ownership of Adaptive Tutorials

To-date, four Adaptive Tutorials in the 1st and 2nd year mechanics courses have been implemented, targeting fundamental concepts (Figure 2). Several strategies were implemented to examine the usefulness of the educational resources in improving learning in Mechanics of Solids courses. Evaluation strategies have included a comparison of guided vs. discovery based learning tasks, comparing performance across different cohorts of students with and without access to the Adaptive Tutorials and looking at overall student satisfaction and performance after using adaptive tutorials. Results support the benefits of Adaptive Tutorials for learning as well as for giving teachers control of the learning process (Prusty, Ho and Ho 2009).

In light of the aforementioned challenges in engineering education, and based on the success of the pilot study at UNSW, a new ALTC project was funded that seeks to develop and disseminate Adaptive Tutorials in five universities in Australia. While the strategy for incorporating teachers as pedagogical owners through their roles as it is derived from VAF seems to have worked well at one university, the challanges associated in diffusion of such innovation into a multitude of institutions suggest that a community of practice appraoch might be needed. There is a growing recognition of the importance in using communities of practice (CoP) as a model for teacher professional development, and in particular, to support teachers and educators in reflecting on their practice, in a collaborative and

supportive environment (Schlager, Fusco and Schank 2002). Such a models fits well with the desire to increase the adoption of Adaptive Tutorials by emphasizing reflection and adaptation. The CoP will first identify a set of threshold concepts (Meyer and Land 2005) that inhibit students' learning, and then to develop Adaptive Tutorials to target them. The threshold concepts will be identified through group discussions, drawing on the shared experience of the academics involved. The Adaptive Tutorials that will be developed will support guided learning with an emphasis on "learning by doing".

Figure 2: Snapshots of piloted Adaptive Tutorials in Engineering Mechanics at UNSW

Conclusion

This is a "towards" paper, describing work *in progress* that seeks to establish a community of practice concerning the use of Adaptive Tutorials. The rationale behind the approach was derived through an analysis that culminated in the understanding, that the role of teachers in using educational technology is that of educational action researchers. A case was made for promoting teachers' *pedagogical ownership*, which emphasises the ability to perform *reflection* and *adaptation*, as a principled strategy for tackling the problem of diffusion of innovative educational technology. The successful case of introducing Adaptive Tutorials at UNSW provides evidence that technologies that promote pedagogical ownership are likely to be adopted by teachers.

In order to scale and introduce Adaptive Tutorials across a variety of institutions, a community of practice approach is suggested. The CoPs' focus on sharing reflections that stem from teachers' practice suits particularly well in this case, exactly because reflection is a key component of pedagogical ownership. The CoP will identify threshold concepts in Engineering Mechanics, and subsequently develop Adaptive Tutorials which target them. In time, more information on the success, or lack thereof, of the strategy will be disseminated.

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