AC 2007-117: ELECTRONIC COURSE PACKAGING FOR STATICS AND DYNAMICS: A REVIEW OF EFFORT, REWARD AND POTENTIAL

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Electronic Course Packaging for Statics and Dynamics: A Review of Effort, Reward and Potential

Abstract

This paper describes the deployment of an electronic compilation, known here as an ePAC, in Statics and Dynamics courses. A primary objective was the development of a more efficient means to deliver introductory mechanics. In this context efficiency means maximizing the rate of material assimilated by students, while maintaining course integrity, student satisfaction and enjoyment levels.

An essential feature of the methodology was that all course elements, except tests, were available online at registration time. Onus was placed on self-directed study at a student's convenience, with the professor adding enrichment in class. A commercial software served as the workhorse for most of the symbol and number manipulation required for the solution of textbook problems.

The courses that are the subject of this paper were delivered using an electronic course package with the following components:

1) The framework was a commercial course management system (CMS).
2) Two recently published e-texts were employed, allied with evolving, and somewhat problematic, solution manuals.
3) Online tests were used with automatic marking of tests and assignments. What was gained and what was lost with synchronous marking is discussed.
4) The instructor's e-lecture notes amplified, simplified and clarified the textbooks. The students were provided with all lecture notes upon CMS registration.
5) Students solved text and test problems with the aid of a proprietary equation solving software. This approach was well suited to online problem sets, with input data refreshed at each student solution attempt. If stuck, students e-mailed their computer models to either the TA or the instructor, providing, at times, almost 24/7 access to help.
6) Students taking introductory mechanics may have unpredictable math and computer backgrounds, and an equation solving software can be a great leveler. To minimize software learning time students were provided with a course specific, instructor authored, software supplement. They were encouraged to read the supplement before the first day of lectures. About sixty interactive models and six animated screen videos prepared the student for self-test exercises. About ten hours were required for a student to assimilate the material in the software supplement, and the paper discusses the value of this time commitment.
7) The role of virtual laboratory exercises included in the ePAC is briefly described.

Introduction

Improvements in online learning tools, evolving student demands and universal computer access, prompt the initiation of course delivery methods that challenge the hegemony of traditional presentation formats. The courses described here were not offered by distance delivery, but the concept of electronic bundling has features in common with online education, particularly the

attraction of studying anywhere, anytime. In a comprehensive review of online engineering education, Bourne[1] has discussed aspects of relevance to the ePAC concept.

The contents of Statics and Dynamics are structured and circumscribed; the means of delivery is less so. Electronic packaging can be an appropriate teaching aid, and a discussion of this type of course format is particularly relevant to introductory courses, where class sizes are often large, and there is much material to be covered.

The present work describes a protocol where course elements were electronically bundled and provided to students at the start of the course. An objective was to remove the time constraint imposed by the familiar lecture-by-lecture information release. The instructor unified the various course elements with both e-lectures, and "on stage" instruction.

Prince[2], in a review of active learning techniques in engineering, has stressed the need for "… faculty to think about teaching and learning in nontraditional ways". Active learning was prevalent in the courses described here. Electronic lectures, a computational software supplement and virtual experiments required students to study and self test at their convenience. Passive "sit and listen" sessions were minimized.

Active learning notwithstanding, an ePAC delivery should not have the effect of placing a significant additional learning stress on the course taker. The arrival on day one of a large volume of reading material and exercises could well cause some student concern. To reduce this effect "progressive scaffolding", as discussed by Hall[3], was a pervasive ePAC feature. Progressive scaffolding meant that students were taken through topics in small increments, and were introduced to learning techniques that eased stress and increased confidence in their problem solving abilities.

Packaging obviously entails considerable preparation and did not lead to a reduction of in-session demands on the instructor. However, limitations imposed by class size and student availability began to dissolve.

A student often misses some live lectures, and either mishears or misunderstands parts of others. Packaging obviated much of the negative effect of "lost" time, and the ability to pause and rerun e-lectures enhanced comprehension.

Electronic course bundling can contend to be a worthwhile delivery method only if the associated quality of learning and the degree of student and instructor satisfaction, at least asymptotically approaches these aspects of a well constructed non-bundled offering. Quality of learning and course satisfaction are elusive to quantify, but the author's experiences with ePAC teaching lead to the belief that bundling can in fact be a superior format. Live lecturing, and week by week delivery may be a "glass ceiling"; ePAC performance can in fact not only equal, but can exceed the outcomes of more traditional presentation methods. Course packaging aligns well with time constraints imposed by students' non academic work demands. Engineering students (and professors) have an appetite for electronic information sharing; an ePAC course can be pleasantly addictive and entertaining for both parties.

A schematic for the electronic packages used in recent Statics and Dynamics courses is shown below, and details of the components will now be addressed.

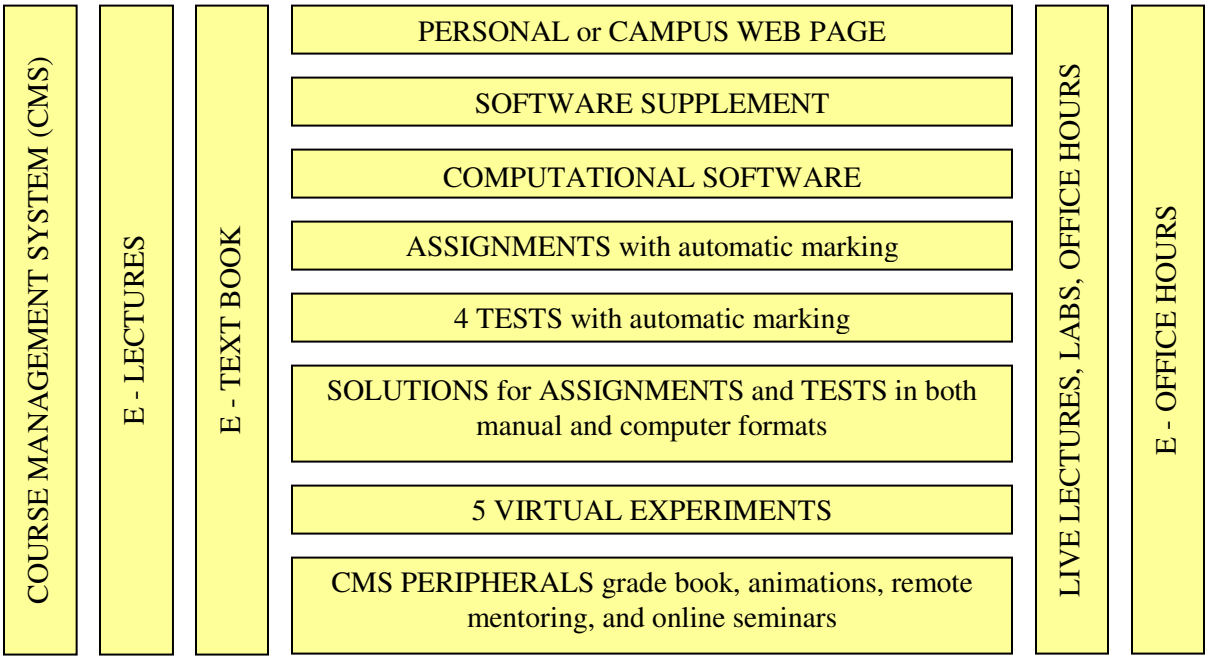

Fig. 1. An overview of an electronic package for either Statics or Dynamics.

The Components of the Electronic Package

Some of the ingredients were as commonly featured in most Statics and Dynamics courses, but packaging required that the role of each element be re-examined. Efficient use of the learner's time was paramount, so content overlapping and student internet meanderings were avoided.

Personal or Campus Webpage

The instructor's webpage[4] featured a ninety second course promotional video. This was professionally[5] made, at a cost of about $4500 CAN, using a "made-in-house" video as a starting point. It was difficult to know if this was money well spent, but the video did help to give prospective students a preview of an ePAC course, and to trigger an interest in the ePAC delivery format.

Computational Software Supplement

The computational software[6] had a comprehensive user manual, quick start guide and user friendly help menus. However, of necessity, the commercial aids were not course specific. The author found that student software learning time was reduced by using a supplement written to suit the specific requirements of Statics and Dynamics. Previous courses had been offered using TKSolver, but without a supplement, and the software learning time tended to be excessive.

Progressive scaffolding was very much in evidence in the supplement. It was assumed that students had no prior experience with the software, so steps were small and numerous. The supplement was designed to enable the learner to work alone immediately, although a small fraction of lecture time was devoted to ensuring that everyone had enough knowledge to begin using the software for problem solving.

The supplement printed to about sixty pages, but with about forty pages of illustrations it was relatively easy reading. The illustrations were linked to active models, as shown in Fig. 2. The student needed to have access to TKSolver to use these models, and could modify and save any files created. There were numerous self tests with solutions. The software was installed on the campus server for in-house use, and students could buy a copy from the campus bookstore, or purchase online.

The supplement had various Macromedia Captivate[7] screen history animations, with instructor narration. Each of these animations ran for about three minutes and was free-standing i.e., could run without access to the source software. A link to the supplement appeared permanently on the personal webpage, allowing access prior to course registration.

About ten hours were needed for a student to work through the supplement, and some resistance to this active learning task was encountered. As suggested by Felder and Brent[8], the author made certain that students were aware of the future benefits of this investment of time and effort.

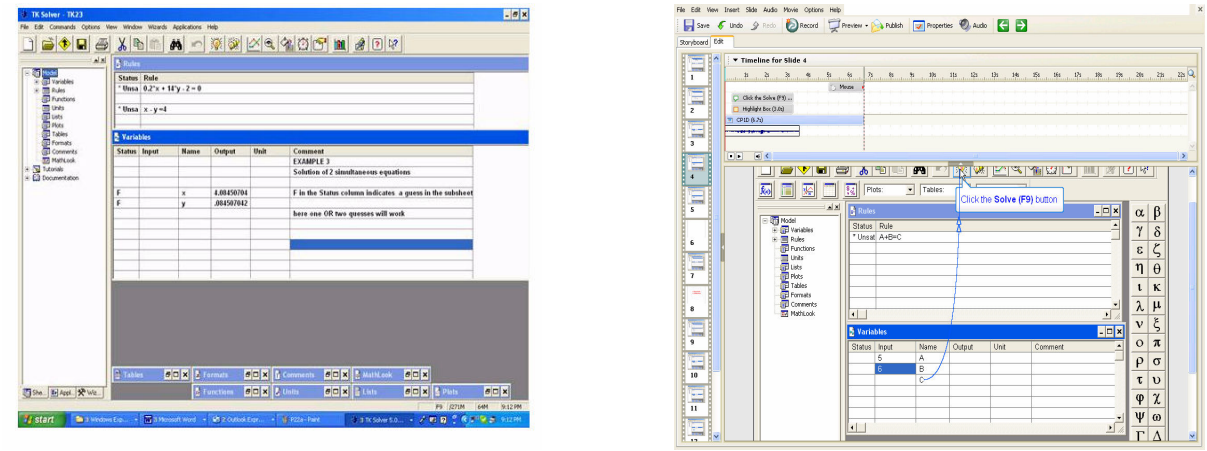

Fig. 2. An interactive TKSolver model from the computational software supplement, and an image from a four second slide in a Captivate animation. The instructor's cursor movements were tracked and shown with text boxes as desired. Multiple sound tracks were available for voice-over, music and audio special effects.

Computational Software

The author has found TKSolver to be a worthwhile adjunct in introductory mechanics courses. TK, as appearing in Fig. 3, has many features that facilitate the solution of mechanics textbook problems. The course essential aspects of TK were introduced to students in the supplement discussed above.

The TK contribution, in the context of Statics and Dynamics, was mainly number and symbol manipulation. Providing a student with a number handling device is hardly controversial, but an equation solving assistant is another matter. A feeling persists that a "manual" solution, using a handheld calculator, is the preferred technique. The use of TK did not extend the range of problem types that students could solve – the concepts of mechanics that were addressed were the same as in a non software aided course.

Students wrote code in TK's Procedure Function Subsheet for the solution of first order differential equations. Also, used in a limited way, was the TK library of algorithms for the solution of differential equations of various types and orders.

The possibility of degradation of student math skills caused by the use of computational software was a concern. Computer aided solutions offer their own type of mathematical challenge. The student must have the ability to model the problem, generating the equations that constitute the solution, and then declaring the equations in TK format. The software performs a black box search for numerical values that satisfy the equations. The problem solver must keep control of the solution, ensuring that independent equations and unknowns are equal in number. Equations with multiple roots must be identified, and an appropriate starting guess used for iterative solutions must be chosen to ensure convergence to the desired root. The learner gains a new set of math skills, with some loss of practice in routine manual calculations.

Desirable features of the computational software used in the ePAC included the following:

1) Low cost – the software was a course add-on, and it was important not to significantly increase the course cost to the student.
2) Short learning time – it was important to minimize time spent on material other than mechanics.
3) Longevity and convenient to run – software that was antiquated, or with operational requirements beyond that commonly available on a home computer, were avoided.
4) Input data had to be easily changed to accommodate the repetition of solutions with data changes at each attempt.

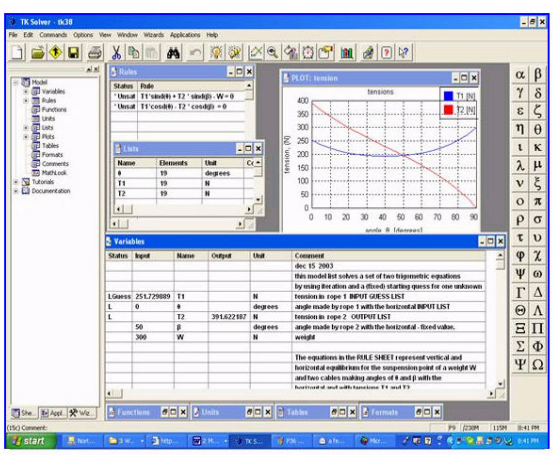

Fig. 3. The computational software generated global solutions quickly and easily. Plotting helped students gain insight to a problem.

Course Management System, CMS

Most universities have an in-house CMS such as WebCT, and this was examined as a first choice organizer. However, the author found that an off-campus commercial CMS[9] was a better option. Statics and Dynamics are dependent on textbook usage, requiring a user fee if text material is placed on the campus server. In the rare instance of an instructor having copyright ownership of all the course material, then an in-house CMS might be a preferable route.

Using a commercial server for the supply of vital course components caused concerns about institutional liability in the event of server failure. However, in the author's experience, server down time over two years has been almost zero, although some operational defects did have to be accommodated.

Students purchased the CMS access code, either online or from the campus bookstore. Nearly all of the students bought both access code and the hardcopy text, reflecting the feeling that hardcopy reading was easier than reading from a screen.

Navigating with the CMS was effortless in both instructor and student views, with some minor nuisances. Involuntary logoff occurred too rapidly. Making alterations to assigned work created a new assignment which awkwardly coexisted with the old assignment. Exporting from the grade book to Excel never worked properly. With the publisher's help, some of these flaws were eliminated.

E-Lectures

In the courses discussed here, about one half of the course lectures were electronic. E-Lectures presented an opportunity for the instructor to impart a personal imprimatur to the ePAC, as illustrated in Fig. 4. Although content inevitably followed the textbook, problem solving techniques, nomenclatures and mathematical techniques were the instructor's choice.

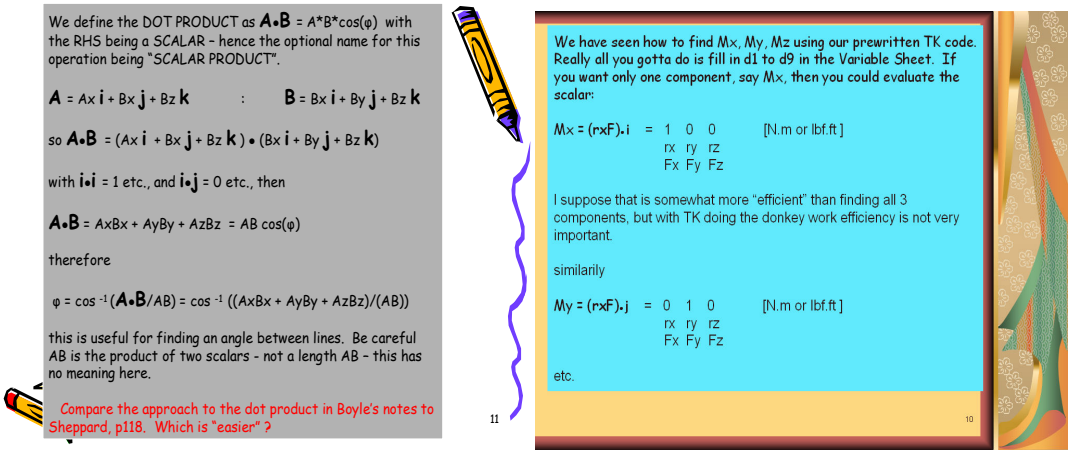

Fig. 4. PowerPoint e-lectures had narration, animations and music.

E-Books

Recently published Statics and Dynamics texts[10, 11] were CMS embedded, and all course reading and assignment problems were drawn from these texts. After an unsuccessful attempt at solving a problem students were given a hint which directed them to re-read certain parts of the text. Feedback suggested that this feature was not particularly helpful because the reading suggested by the CMS tended to be too general.

Having the text and illustrations available on screen during lecture periods was helpful, dispensing almost entirely with the use of overhead transparencies and board drawings.

Using recently published texts was refreshing, but the instructor needed to be vigilant regarding text and solution manual errors. A revised (rather than a second edition) version of the Statics text[12] appeared after the author's courses was over. The revision comes with a conversion chart to show improvements over the original. The author had noted during course usage that text revisions were, and indeed still are, needed.

Assignments with Automatic Marking

The CMS provided a list of text problems from which assignments were created, automatically marked and recorded in a grade book. Annoyingly, the list did not include all of the text problems, but with some additional labour the missing questions could be extracted from the e-text and used as instructor created exercises. The instructor had control over assignment features such as the number of attempts allowed, the required precision, when hints were given and the question weighting. Non-numerical assignments, such as text reading and free body diagram drawing, were used in a limited fashion without marks being given. As part of doing an assignment students were encouraged to import free body diagrams to the Mathlook sheet (an active notepad) of TKSolver.

Students enjoyed automatic marking, particularly the immediate reception of marks, but obviously the concept raises some questions. The instructor maintained contact with assignment work by the e-mail exchange of computational models. Handwritten work was not accepted, but rather a student seeking help mailed a partially complete TK model. Sometimes this model was beyond resuscitation, but often a "nudge" from the instructor undid the deadlock. A teaching assistant lightened the load of dealing with assignment queries, and provided help at well outside normal business hours.

Students saved completed models and could access these models for test purposes. Libraries of models were amassed as the courses progressed, with hardcopies kept for inspection and constructive criticism.

The use of automatic marking did remove some of the traditional professor/student interaction provided by assignment correcting. Also, additional responsibility was placed on the student to persevere in finding the reason for an incorrect answer.

Tests with Automatic Marking

For each course, four online tests, each of two hours duration, were administered. The tests were open book and students could access their collection of computer models. This might seem to have been overly generous, but in practice a good familiarity with the models was needed to make their use in a test a worthwhile option. Questions were either drawn from the CMS question bank, or were instructor written. All had random number inputs to eliminate copying. Multiple choice questions were an option but were not used.

Problems could sometimes be solved by modifying or merging existing models. With input data changing at each solution attempt, hand calculator solutions were impractical. Solutions were posted online immediately after each test.

Tests were preset to begin and end on the hour, the CMS not allowing half past the hour start or finish. A security loophole became apparent in that sometimes a test would not shut down at termination time, making limitless test duration an embarrassing possibility.

Feedback from students on the automatic synchronous marking of tests was favourable. From the instructor's perspective the issues of administering a test, marking, recording the marks and posting the solutions, could be performed in a closed-end two hour period.

Virtual Experiments

A web search revealed various possibilities for virtual Statics and Dynamics laboratories, but the author found these offerings to be mostly inappropriate due to impediments such as high cost, marginal fit to course content, difficult installation and copyright restrictions.

Statics and Dynamics textbooks usually have computer aided problems at the end of chapters, and these were modified to use as virtual experiments. Also the author has developed a computational method with the coined name "pseudographics". This technique provides full cycle solutions for the kinematics of 2-D and 3-D mechanisms[13, 14]. These models formed a base for a number of virtual experiments in the mechanisms part of the ePAC Dynamics course, with students being required to write code for position, velocity and acceleration. Experiments were limited to planar linkages, with 3-D work being an option for the future.

Students used the programmable Procedure Function Sheet of TK to handle numerical work in dynamics of particles virtual experiments on 1-D and 2-D motion with viscous drag forces. Reports were submitted by e-mail in formats that were very similar to the reports on real world physical laboratory work.

Course Management System Peripherals

The CMS had available a number of non-essential features that were used to varying degrees in the present work:

1) The Grade Book feature was a labour saver. Frequent and detailed posting of marks kept students aware of their status in a course.
2) Animations in the CMS were provided by the publisher, but links to the text were obscure, and student usage was minimal.
3) Remote student mentoring via the CMS was available for some courses, but not for Statics and Dynamics.
4) Short online seminars for both entry level and experienced users were provided by the CMS publisher. It was useful to participate in these seminars.

Live Lectures, Labs and Office hours

The author's home university does not offer, and does not intend to offer in the near future, distance courses in engineering. Also, labour contractual agreements usually require an instructor's physical presence at lectures, laboratory and posted office hour times. These restrictions are the nemeses of the ePAC advocate, making the full spectrum of live activities inevitable.

The ePAC format courses offered by the author have had live lectures, lab and office hours, all with the mandated contact time. The choice of a method of information delivery resided with the instructor, allowing most of the lecture time to be devoted to online learning. The immediate availability of information during lectures required adjustments in lecturing techniques. For example, the CMS provided perfectly drawn diagrams which were transferred to Windows Paint for amplification, as in Fig. 5. No paper was exchanged in either direction between instructor and student in any of the four ePAC course offerings.

As well as having live office hours, the ePAC courses run by the author all employed an open e-office, with home and cell phone access to both the teaching assistant and the instructor. Surprisingly, student use of this service was consistently low, possibly due to easy help access on campus. Larger class sizes might well require a revised approach to the e-office, including the use of a free online "phone" service such as Skype[15].

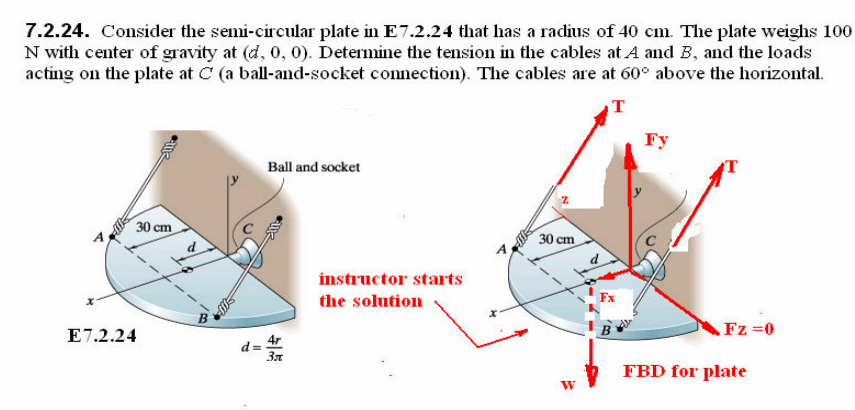

Fig. 5. The CMS gave online access to all e-book diagrams and text. During lecture time Windows Paint was used to enhance textbook illustrations as shown here.

Conclusions

The author's observations on the ePAC project, four courses to date, are experiential rather than statistical in nature. Course evaluations helped with student feedback on the ePAC concept.

1) Students reported satisfaction with the ability to study course material at any time.
2) A considerable allocation of the instructor's time, along with funding and technical assistance, is required in the ePAC start up phase.
3) Electronic packaging produces a visually attractive course assembly that engendered student enthusiasm for the ePAC format.
4) There was no evidence to suggest that using commercial software as a computational aid in a Statics or Dynamics course eroded skills in mathematics. In fact, the author's opinion is that using computational software enhances modeling abilities. This applies to courses with, or without, an ePAC format. Also the repeatability of software aided mathematical operations is very reassuring to a student, with families of text problems being solved with almost identical sets of equations. A statistical investigation is required to further explore the benefits, or otherwise, of computational software in Statics and Dynamics courses.
5) Computational software usage was essential for students to solve problems where the input data changed with each attempt. Frustration and lack of time prohibited the use of handheld calculators.
6) TKSolver was an ePAC asset with a low cost (18$CAN), short learning time and engineering features that could be valuable to a student in the future.
7) The author found that the off-campus commercial server was adequately reliable.
8) Some operational difficulties were encountered with the CMS. The publisher's phone-in help service was rapid and reactive, but an instructor must be prepared for unpleasant surprises when working with a CMS.
9) E-book problems with incorrect CMS answers caused more of a perturbation than with similar hardcopy text errors. Students who submitted a correct answer received a zero mark, and had to submit a wrong answer to receive a non-zero score!
10) The publisher's editing of the e-book and associated problem sets and solutions was inadequate. A revised edition of the Statics text was released after the author's courses were completed, but a cursory look revealed that the revisions were not complete. The author appreciated that the error free first edition of a text, and the associated solution manual, do not exist. There was however, a danger of an excessive number of errors vitiating a partially online course, where time for textbook remediation is very limited.
11) An ePAC course required some role adjustments. The instructor does more managing and less lecturing. A teaching assistant takes on duties as web assistant. Students assume a more active role with e-lectures, assignment error tracking and self-help virtual labs.
12) An instructor considering the deployment of an electronically packaged course must be careful not to contravene labour contracts.
13) An ePAC course designer must ensure that engineering accreditation requirements are satisfied – the Canadian Engineering Accreditation Board (CEAB) was the governing body in the context of the present work.

14) An ePac has components that require a contribution by agencies that are not under the instructor's control. Ongoing and adequate emergency plans should be on hand to prevent a "house of cards" condition in the event of, for example, an unexpected server interruption.

Effort, Reward and Potential

This paper's title promises revelations on these topics. Effort refers to the instructor's labour commitment, over and above that of a non electronically bundled course. Considerable front-end effort makes an ePAC format worthwhile only if the format is to be used in a series of courses. Reward refers to benefits arising from features that are unique to an ePAC. Potential refers to possible development of the ePAC, with some of the improvements lying outside this author's control.

Effort	Rewards/Achievements	Potential/Work to be done
CMS set-up time was considerable. Online seminars were required.	Once running the CMS was a time saver and exciting to use.	Publisher should try to reduce the number of CMS glitches.
TKSolver models had to be created for all text problems.	Models provide immediate solutions for all data inputs and were helpful in unraveling solution manual errors.	Publisher should try to reduce the number of differences between hardcopy and e-book versions of text problems.
Production of promotional video for $4500 CAN.	Debatable return for effort.	A more course specific, made-in-house promotional video is underway.
Production of TKSolver supplement.	A worthwhile student learning aid, informative and providing a fast start up.	The supplement could be shortened by 20%.
E-Lecture preparation.	Reduced whiteboard activity in class. A superior set of instructor's notes evolved with narration, animation and sound effects.	It is satisfying to gradually make the contents both better and more comprehensive.
E-Book deployment required minimal effort.	Gave in-class access to diagrams and simulations. Automatic marking has attractions, and some obvious drawbacks in terms of reduced contact with the students' calculations.	Publisher could supply a more complete set of assignment problems. Solutions to the electronic book questions might allow tracking of the cause of erroneous answers. Improved arrangements for examining students' unsuccessful solution attempts are required.

Virtual experiments were created, either from scratch or from text 'computer' problems – very time consuming.	Future value remains to be seen.	Further development is needed to acquire a good fit for virtual experiments in an ePAC setting.

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