Dynamic and static worked examples in student learning

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***Abstract**: This paper investigated the effectiveness of static (text and pictures) and dynamic (video plus audio) worked examples in student learning. Seventy-one RMIT students enrolled in a third year unit on electronic engineering used both dynamic and static recordings of solutions of tutorial problems. It was found that students did not use worked examples regularly, but studied them just before events of summative assessment. The majority of students did not download worked examples, but rehearsed directly from the RMIT unit site. Student perceptions that dynamic worked examples significantly helped them in improving their course knowledge was supported by statistically significant improvement in final examination performance attributed to dynamic worked examples.*

Introduction

The effectiveness of worked examples in instructional guidance has received a considerable amount of attention from researchers (for a review see Atkinson, Derry, Renkl, & Wortham, 2000). In 1985, Sweller and Cooper compared the impact of worked examples and conventional problem solving on acquisition of problem solving skills in students studying algebra. They found that worked examples imposed lesser cognitive load than conventional problem solving and, therefore, required shorter study time than conventional problem solving (Sweller & Cooper, 1985). Sweller and Cooper posited that this inefficiency of conventional problem solving was due to a significant cognitive load imposed on the students by the means-ends analysis, which is normally used by novices to resolve problems in semantically rich knowledge domains (Chi, Glaser, & Rees, 1982). Studying worked examples was much less cognitively demanding, and therefore, it resulted in more efficient student learning. Since 1985, similar results were obtained by researchers in statistics, computer science, physics, etc, further suggesting that worked examples are more effective in enhancing problem solving skills than conventional problem solving, (Kalyuga, Chandler, & Sweller, 2001; Paas & Merrienboer, 1994; Sweller, 1999).

The effectiveness of worked examples as an instructional device for a novice to acquire problem solving skills is not wholly unexpected – worked examples provide 'expert' solutions that students can emulate. Worked examples are extensively used in engineering and science education. Most textbooks in engineering, mathematics and science contain extensive sets of examples that can be studied by students in their own time. Until recently, most worked examples provided to engineering students were 'static' and were distributed as printouts, pdf and MS Word files. Static worked examples usually contain a problem statement, diagrams and pictures required to appropriately categorise the problem, steps taken to solve the problem, as well as necessary comments on the solution process.

Rapid increases in computer power as well as the expansion of the world-wide-web have created opportunities for educators to offer students 'dynamic' worked examples – solutions that incorporate both visual and sound instructions and can be watched over and over again (Moreno & Mayer, 1999; O'Shea, 1999; Patel & Feinson, 2005; Wandel, 2009, 2010). O'Shea reported positive student opinions on videotaped tutorials for his communication engineering subject (O'Shea, 1999). Patel and Feinson used Camtasia Studio to create video illustrations on particular spreadsheet applications for solving statistical problems. Student surveys showed that these video illustrations not only engaged students in using spreadsheet applications more effectively, but also made them enjoy statistics (Patel & Feinson,

2005). Wandel used videos of worked solutions recorded by Camtasia Studio on a tablet PC in his classes on thermodynamics, and found that students perceived the dynamic worked examples as very helpful in their learning (Wandel, 2009). Moreover, he found that students liked the videos more than their static snapshots (provided to students as pdf prints). Wandel also collected student survey responses that suggested they were using dynamic worked examples during the semester on a regular basis (Wandel, 2010). Due to the small number of survey participants, Wandel was unable to establish statistical significance in his findings (Wandel, 2009, 2010).

This study intended to seek further evidence of the effectiveness of worked examples. It attempted to provide more insight on: (i) patterns of usage of worked examples during semester; (ii) students' perceptions on the impact and convenience of static and dynamic worked examples; and (iii) impact of dynamic worked examples on students' performance.

Methodology

In semester 1 of 2011 (12 teaching weeks from March to May), the author coordinated a third year unit on electronic engineering with 71 students enrolled. Unit weekly activities consisted of two one-hour lectures, one one-hour tutorial and one two-hour laboratory session. All lectures and tutorial classes were conducted by the author. Students were divided into two tutorial groups.

All students were offered both dynamic and static worked examples – recordings of solutions for the problems that were considered during tutorials. Dynamic worked examples were recorded as mp4 files with the Camtasia Studio 7, using a tablet PC after both tutorial sessions for the week were conducted. These dynamic worked examples were of 14 to 28 minutes duration. Static worked examples contained live tablet PC recordings of both weekly tutorials, which were printed as pdf files. Both dynamic and static worked examples were uploaded to the unit website at RMIT Learning Hub (BlackBoard) by the end of the appropriate study week. Ten static and 10 dynamic worked examples were created. Static worked examples could be downloaded from the date they were uploaded. In order to collect accurate usage statistics for dynamic worked examples, they were made downloadable only after the end of the semester – in week 13. During semester students were only able to watch the dynamic worked examples on the RMIT Learning Hub.

Three sources of data were exploited in this study. Firstly, the number of hits for both static and dynamic worked examples were monitored. Secondly, in week 16, just three days before students sat the final unit examination, they were asked to participate in a short on-line survey administered via Survey Monkey. This survey consisted of both evaluative statements and descriptive questions. Most of the evaluative survey statements were paired; students were asked to appraise static and dynamic worked examples separately. All evaluative statements were gauged using a Likert-type scale from 1 (Strongly disagree) to 5 (Strongly agree). Participation in the survey was not compulsory. Thirty students took part in this survey.

Thirdly, students' performance in final examinations in the years 2009, 2010 and 2011 were compared to establish the impact of dynamic worked examples on learning outcomes. In 2009 and 2010, this electronic engineering unit was also coordinated by the author. All lectures and tutorial classes were also delivered by the author. Final examinations in all years were open-book, contained four descriptive questions and were of two hours duration. All examination papers were graded by the author. There were two important differences between the units in 2009, 2010 and 2011. Although static worked examples (recorded on a tablet PC during tutorials) were uploaded in all three years, dynamic worked examples were available only in 2011. Also, in 2009 and 2010, weekly tutorial classes were of two hours duration. Consequently, students in 2009 and 2010 attended 12 more hours of tutorials and, on average, resolved twice as many tutorial problems than the students in 2011. Moreover, because of the longer tutorials, static worked examples available to students in 2009 and 2010 consisted of twice as many resolved problems as static worked examples offered in 2011.

Research Data

Usage statistics

Contrary to the findings of Wandel (Wandel, 2010), students in this study did not use worked examples regularly during the semester. Instead, they devoted their time to worked examples just prior to incidents of summative assessment – either before two tutorial tests (conducted during tutorial sessions) or just before the final course examination. Figure 1 depicts a distribution of use of a static worked example uploaded in week 5 of the semester (30 March 2011).

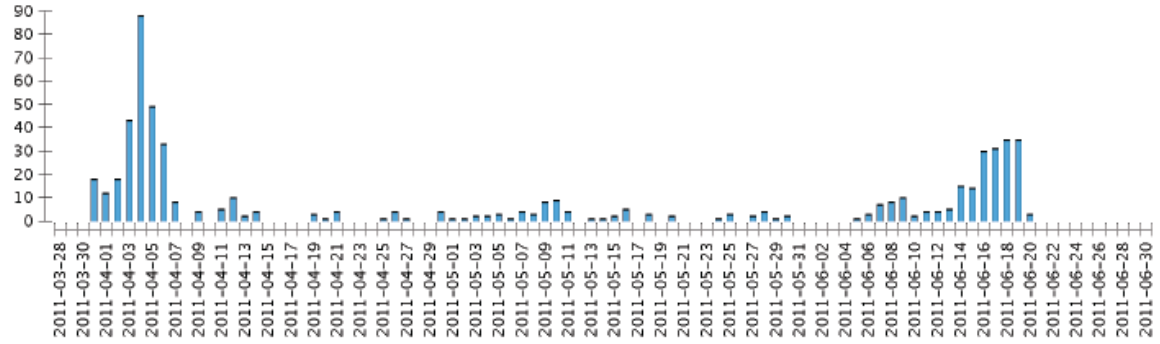

Figure 1. Usage of the static worked example uploaded in week 5.

During 11 weeks of being available on the RMIT Learning Hub, this static worked example was used by students 584 times. As suggested by the distribution displayed in Figure 1, this worked example was extensively exploited by students only twice. They used it just before the first tutorial test, which was conducted in week 6 (on the 6th and the 7th of April) and, 10 weeks later, over a few days preceding the final examination (conducted on the 20th of June).

Figure 2 shows the distribution of hits for the dynamic worked example for week 5 (uploaded on the 30th of March).

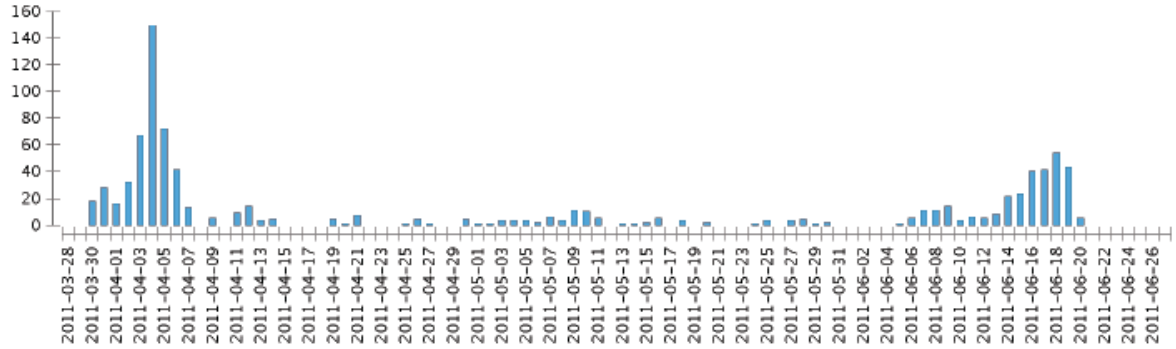

Figure 2. Usage of the dynamic worked example uploaded in week 5.

The pattern of usage of the dynamic worked example for week 5 was similar to that of the static worked example pictured in Figure 1. The majority of students worked with it on only two occasions – while preparing for the tutorial test in week 6 and during study for the final examination. This dynamic worked example received 860 student hits.

Survey results: paired survey statements

Paired-Samples T-tests were used to compare student opinions on the impact of dynamic and static worked examples. The following are statistical results for some of the paired survey statements.

Students found dynamic worked examples much more (and statistically significantly) useful than static worked examples ($t = 4.83$, $df = 29$, $p = 0.000$): *Video Recordings were **extremely** useful in my learning* ($M = 4.93$, $SD = 0.25$), versus *The pdf files of weekly tutorials were **extremely** useful in my learning* ($M = 4.30$, $SD = 0.75$).

Students also believed that dynamic worked examples enhanced their unit knowledge much more (and statistically significantly) than static worked examples ($t = 3.29$, $df = 28$, $p = 0.003$): *Video Recordings helped me to **significantly** improve my course knowledge* ($M = 4.83$, $SD = 0.38$), versus *The pdf files of weekly tutorials helped me to **significantly** improve my course knowledge*: ($M = 4.45$, $SD = 0.63$).

Although students used dynamic worked examples during the semester more often than static worked examples, this difference was not statistically significant: *I have used Video Recordings **extensively** during 12 weeks of a semester* ($M = 4.41$, $SD = 0.63$) versus *I have used the pdf files of weekly tutorials **extensively** during 12 weeks of a semester* ($M = 4.21$, $SD = 0.73$).

No statistical significance was established between the usage of the two kinds of worked examples before the examination: *I have used Video Recordings **extensively** to prepare for the final examination* ($M = 4.77$, $SD = 0.63$) versus *I have used the pdf files of weekly tutorials **extensively** to prepare for the final examination* ($M = 4.63$, $SD = 0.56$).

Students thought that they used both dynamic and static worked examples much more extensively before the final examination, than during semester:

*I have used Video Recordings **extensively** to prepare for the final examination* ($M = 4.77$, $SD = 0.63$) versus *I have used Video Recordings **extensively** during 12 weeks of a semester* ($M = 4.41$, $SD = 0.63$), ($t = 2.77$, $df = 28$, $p = 0.01$); and

*I have used the pdf files of weekly tutorials **extensively** to prepare for the final examination* ($M = 4.63$, $SD = 0.56$) versus *I have used the pdf files of weekly tutorials **extensively** during 12 weeks of a semester* ($M = 4.21$, $SD = 0.73$), ($t = 3.26$, $df = 29$, $p = 0.003$).

Survey results: descriptive questions

Only three out of the 30 survey participants believed that static worked examples helped them more than dynamic worked examples. The remaining 27 students showed a preference for the dynamic worked examples. The following are some student comments on the reasons behind their choices (quoted exactly):

> *The comments made in the videos include reasoning why things are done, plus other information that you cannot get from a solution paper. Although the pdfs are more extensive in that they answer more questions, i find once going through the video, i am very confident to complete similar questions posed in the tutorials*
>
> *... the Video recording gives an easy step-by-step approach whilst trying to decipher the process from a pdf can be challenging - especially when time is critical. I do like how each session is included on the tutorials so if you remember a specific marking or drawing you can instantly relate to it again.*
>
> *The pdf files are great to have at hand but they are simply the final solution of all written values where as the video explains how each line is created, where the values came from, so its far easier to follow and by far made the year alot more easier and the content more understandable! As long as i see where all values come and go, i will understand, and this is EXACTLY what the videos have done!*
>
> *The comments made during the videos are information you cannot get from the solution sheets. I go through the video and copy out everything written plus what is said. I learn best from writing down things, so, in this way the videos have been very useful*
>
> *Both are good, with the pdf I can print and view it. With the video recordings I can focus on the audio explanation from the lecturer. It is better to have both.*

Impact of dynamic worked examples on students' final examination performance

In order to judge the impact of dynamic worked examples on learning outcomes, students' final examination performances in 2009, 2010 and 2011 were compared using the Independent Samples T-Test. As discussed in the Methodology section, examination papers in all three years were similar; they were conducted as open-book, were of two hours duration and were graded by the same person. The maximum mark available for each of the three examination papers was 100.

As anticipated, students' performance in final examinations in 2009 and 2010 were not statistically significantly different: $t = -1.35$, $df = 125$ (2009: 64 students, $M = 48.3$, $SD = 20.9$; exam 2010: 63 students $M = 43.4$, $SD = 19.4$). This result was expected. In 2009 and 2010, unit study activities and unit final examinations were very similar.

Examination in 2011 (71 student, $M = 59.8$, $SD = 26.0$) recorded a statistically significant difference in students' performance compared to examinations in both 2009 and 2010. Students in 2011 out-performed students in 2009: $t = 2.81$, $df = 133$, $p = 0.006$ and were significantly better than students in 2010: $t = 4.08$, $df = 132$, $p = 0.000$. Although, such a significant difference in performance was envisaged by positive student opinions on dynamic worked examples, it was not entirely certain and predictable.

Discussion and Conclusions

This study once again demonstrated a well-known fact which is yet to be resolved – that students' study behaviours are heavily biased by summative assessment (Boud & Falchikov, 2005). As evidenced by the BlackBoard statistics, very few students used worked examples regularly during semester. Both static and dynamic worked examples were revised by students extensively only just before events of summative assessment; either to prepare for tutorial tests or to study for the final unit examination. Although the author regularly reminded students of the importance of regular study during semester, most students 'worked hard' only in the assessment periods. Interestingly, students' survey responses contradicted the BlackBoard statistics. Their agreement with the statements on the regularity of usage of worked examples during a semester was considerably strong: *I have used Video Recordings **extensively** during 12 weeks of a semester* ($M = 4.41$, $SD = 0.63$) and *I have used the pdf files of weekly tutorials **extensively** during 12 weeks of a semester* ($M = 4.21$, $SD = 0.73$). Such a discrepancy between student perceptions and reality can be explained by retrospective over-estimation of actual practice (Charness, Tuffiash, Krampe, Reingold, & Vasyukova, 2005). Nevertheless, educators need to be aware of this unexpected discrepancy and employ more effective methods to engage students in regular study during semester.

The fact that 71 students in 2011 opened the static worked example, which was uploaded to RMIT Learning Hub in week 5, 584 times was unexpected. Statistics of use of other static worked examples was similar – on average they were viewed by a student more than 6 times. All static worked examples were available for download from the date of uploading, and it was anticipated that students would download the pdf files of static worked examples when they open them for the first time. Five hundred and eighty four hits made by 71 students over 11 weeks suggests that the majority of students did not download this static worked example to their own computers, but studied it from RMIT web storage instead. This student preference to study on-line suggests that academics need to consider providing more resources to students in electronic form and to upload more resources to the unit learning websites.

The effectiveness of dynamic worked examples was supported both by student opinions and by the unexpected impact of dynamic worked examples on students' examination performance. Notwithstanding that such a result was probable, it was not entirely straightforward and predictable. Because of the changes made to the unit in 2011, semester tutorial hours shrunk from 24 hours to 12 hours. The gap produced by lost tutorial hours was filled by 10 dynamic worked examples. These 10 dynamic worked examples, which were just over three hours duration in total, impacted students' examination performance more than 12 hours of additional supervised tutorials that were offered in

2009 and 2010. Although this outcome seems valid, examination marks in 2011 could have been higher due to many factors (e.g. students in 2011 may have had better prior knowledge in electronics). Therefore, additional validation of the effectiveness of dynamic worked examples is needed. It is clear, however, that engineering educators developing new educational resources need to consider developing dynamic worked examples that permit students to expand their self-learning.

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