Impact of dynamic (videotaped) worked examples on knowledge transfer

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Structured abstract

BACKGROUND

The effectiveness of worked examples in instructional guidance has received a considerable amount of attention from researchers. 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 (DWE) – solutions that incorporate both visual and sound instructions and can be watched over and over again (Belski, 2011; Moreno & Mayer, 1999; O'Shea, 1999; Wandel, 2010). It has also been reported that when students have been offered a set of dynamic worked examples to supplement their face-to-face learning their examination performance in that year improved significantly (Belski, 2011). However it is not yet clear whether DWE impact on knowledge transfer, and if so whether it is near or far transfer that is most affected.

PURPOSE

This paper investigates whether significant improvement in student examination performance that occurred as a result of the provision of DWE, was related to its usage patterns and impact on near or far knowledge transfer.

DESIGN/METHOD

In order to judge the impact of DWE on knowledge transfer and student performance, students’ final examination performances in 2009 and 2010, when DWE were not available, have been compared with results from 2011 and 2012, when students were offered 10 DWE, this was done in pairs due to the style of questions asked, pair one included 2009 and 2011 performance and pair two included 2010 and 2012 performance. Student access of DWE was closely monitored and recorded. These DWE were closely related to the course content and were somewhat similar to problems students faced during their final examination. Examination papers in all four years were similar; they were conducted as open-book, were of two hours duration and were graded by the same person. Each examination consisted of at least one ‘far transfer question’ and two or more tasks that only required near knowledge transfer to solve them.

RESULTS

Improved student performance on examinations in the years that DWE were provided (2011 and 2012) was found to be linked specifically to the questions requiring students to engage in far knowledge transfer; pair one 3.6/25 in 2009 compared to 11.3/25 in 2011 ($t=5.1$, $df=133$, $p<0.001$), and pair two 9.4/25 in 2010 compared to 15.4/25 in 2012 ($t=4.2$, $df= 121$, $p<0.001$). No statistically significant differences were observed for isomorphic questions requiring near knowledge transfer across the 4 years. The investigators also observed very high student access rates of the DWE compared to the SWE specifically during the exam preparation time.

CONCLUSIONS

Engineering and science educators developing new educational resources need to consider developing DWE that permit students to expand their self-learning and enhance their far knowledge transfer skills.

KEYWORDS

Worked examples, problem solving, multimedia learning.

Introduction

The effectiveness of worked examples (WE) in instructional guidance has received considerable attention (for a review see Atkinson, Derry, Renkl, & Wortham, 2000; van Gog & Rummel, 2010). In 1985, while investigating students studying algebra, Sweller and Cooper discovered that WE imposed lesser cognitive load than conventional problem solving. As a result, students studying WE needed less time to acquire certain knowledge compared to students learning by problem solving (Sweller & Cooper, 1985). Sweller and Cooper posited that while problem solving students utilised the strategy of the means-ends analysis that imposes significant cognitive load on them. Studying WE, on the other hand, was much less cognitively demanding, and, therefore, it resulted in more efficient student learning. Since 1985, similar conclusions have been made in multiple areas of learning including: statistics, computer science, physics and electrical engineering (Kalyuga, Chandler, & Sweller, 2001; Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Moreno, Reisslein, & Ozogul, 2009; Paas & Merrienboer, 1994; Schwonke et al., 2009; Sweller, 1999). Some researchers have also reported on near and far transfer gains that were caused by studying from WE (for a review see McLaren, Lim, & Koedinger, 2008).

Transfer of Learning/knowledge has been described as the application of skills, knowledge, and/or attitudes that were learned in one situation to another learning situation (Perkins & Salomon, 1992). The terms of ‘near’ and ‘far’ transfer were introduced by Clarke and Vogel who analysed knowledge transfer that resulted from formal training (Clark & Voogel, 1985). The former relates to transfer of knowledge when training and test settings are similar; the latter refers to dissimilar training and test context, where students are required to apply the skills and concepts learned to new and more complex problems they have not previously solved.

Worked examples represent ‘expert’ solutions that students can emulate and, therefore, are extensively used in engineering and science education. Until recently, most WE supplied to students were ‘static’ and were distributed as printouts, pdf and MS Word files. Static worked examples (SWE) usually contain a problem statement, diagrams and pictures required to appropriately categorise the problem, steps taken to solve the problem, and, on some occasions, offer comments on the solution process.

Recent rapid developments in IT have created opportunities for educators to offer students ‘dynamic’ worked examples (DWE) – solutions that incorporate both visual and sound instructions that can be watched over and over again (Belski, 2011; Moreno & Mayer, 1999; O'Shea, 1999; Patel & Feinson, 2005; Wandel, 2009, 2010). Many studies on DWE analysed student perceptions of DWE, but did not investigate the impact of DWE on student learning outcomes. For example, student surveys by Patel and Feinson (2005) showed that their video illustrations not only engaged students in using spreadsheet applications more effectively, but also helped students enjoy statistics. Wandel (2009, 2010), who used DWE in his classes on thermodynamics, found that students perceived the DWE as very helpful in their learning. Moreover, he found that students liked the videos more than their static snapshots (provided to students as pdf prints). Belski (2011) compared student perception on 10 WE that were offered both as 10 DWE and as 10 SWE and discovered that students liked DWE more than SWE and used the former more often than the latter.

Some studies have also investigated the impact of DWE on student performance. McLaren et al. (2008) used DWE (“Flash videos in which narrator solved stoichiometry problems”) in order to establish whether WE when deployed on top of tutorials result in better learning than the tutorials alone. Although the authors were unable to establish statistically significant difference in student performance, it had been found that the students who used DWE required substantially less time to solve isomorphic problems, (problems that have similar structure to the examples presented during instruction and may differ only in their surface characteristics) (McLaren et al., 2008). Belski (2011) investigated the impact of DWE on student learning outcomes of a third year unit on electronic engineering and discovered statistically significant improvement in students' examination performance as a results of offering DWE (Belski, 2011).

This study intended to seek more insight on whether the improvements reported by Belski (2011) were due to the impact of DWE on near and/or far transfer.

Methodology

In order to establish the impact of DWE, students' performances in the final examinations in the same electronic engineering unit were compared for the four consecutive years – from 2009 to 2012. Over the four year period this third year electronic engineering unit was coordinated by one of the authors. Student enrolments in all four years were similar: 64 in 2009, 63 in 2010, 71 in 2011 and 60 in 2012. Unit weekly activities consisted of two hours of lectures, one tutorial and one two-hour laboratory session. All lectures and tutorial classes were conducted by the author. Students were divided into two tutorial groups. Final examinations in all years were open-book, contained four descriptive questions and were of two hours duration. As a rule, two of the four exam questions were isomorphic to problems experienced during the semester (required near transfer). At least one problem was designed to test for far transfer. All examination papers were graded by the author.

There were three important differences in student experiences in 2009-10 and 2011-12. First of all, the duration of weekly tutorial classes was different. In 2009 and 2010, tutorials were conducted for two hours; from 2011 tutorial time was reduced to one hour. Consequently, students in 2009-10 attended 12 more hours of tutorials and, on average, resolved twice as many tutorial problems than the students in 2011-12. Secondly, in 2009-2010 students were offered only SWE; from 2011 both SWE and DWE were available (BlackBoard). Solutions to tutorial problems that were recorded live on a tablet PC during tutorial and were saved as pdf files played the role of SWE. Videotaped solutions of the same set of tutorial tasks became DWE. The latter were recorded as mp4 files with the Camtasia Studio 7, using a tablet PC. These 10 DWE were of 14 to 28 minutes duration. Thirdly, because of the longer tutorials in 2009-10, SWE available to students in 2009-10 consisted of twice as many resolved problems as SWE and DWE offered in 2011-12.

Two sources of data were used in this study. Firstly, the number of BlackBoard hits for both SWE and DWE in 2011 and 2012 were monitored. Secondly, students' performances in final examinations in the years 2009 to 2012 were investigated to establish the impact of DWE on near and far transfer. This was achieved by (i) analysing the overall students' examination performance and by (ii) establishing similar tasks that required near and far transfer over the four years of examinations and comparing students' performance on those tasks.

The second questions presented to students in all 4 examination papers from 2009-2012 were similar and were isomorphic to tasks solved during tutorials, as well as to solutions available as SWE and DWE. These questions required students to establish the same set of characteristics of amplifiers (based on operational amplifier: 2009 – voltage feedback; 2010 – current feedback; 2011 – transconductance feedback; 2012 – transresistance feedback). These questions were chosen to establish the impact of DWE on near transfer.

Two pairs of similar questions were selected to investigate far transfer. The first pair consisted of questions from examinations held in 2009 and 2011 (students in 2011 were offered only the final examination of 2010 for revision, which did not contain a problem similar to the one in 2009). These questions presented students with a Transfer Function (TF) of the circuit (second order with one pole in the right half plane) and expected them to adjust the circuit using appropriate feedback to design a stable circuit with given specifications. These tasks were unusual because they asked students to deal with an unstable circuit (one or more poles are located in the right half plane) that they had not considered during semester. The impact of feedback on the poles of TF was well studied. Nonetheless, neither SWE nor DWE dealt with unstable circuits. Both SWE and DWE considered general behaviours of poles for first and second order systems when feedback is applied.

The second pair of questions that required far transfer consisted of problems from examinations held in 2010 and 2012 (students in 2012 were offered only the final examination from 2011 for revision, which did not contain a problem similar to the 2010 one). These problems demanded (i) establishing a TF of a given circuit, then (ii) applying a specific feedback to it and finally (iii) sketching the Pole-Zero and the Transient response diagrams for the resultant TF. Problems that separately considered all of the three above-mentioned operations were solved at tutorials. Student were also supplied with SWE and DWE (2011-12) that separately covered (i) establishing a TF of a circuit, (ii) applying feedback to a given TF and (iii) sketching the Pole-Zero and the Transient response diagrams. However, all three operations had previously not been considered together. Therefore, it was concluded that no isomorphic task had been considered during semester and solving these two examination problems required students to integrate their knowledge. Hence, these tasks suited testing of far knowledge transfer.

Research data

Usage statistics

In both 2011 and 2012 students used DWE more often than SWE. Table 1 presents the statistics of the usage of SWE and DWE in 2011 and 2012 for the tasks that were related to basic properties of Two Port Networks (the first class test that was held in mid April was related to this material). As shown in Table 1, during semester the SWE on Two Port Networks was used 584 times by students in 2011 and 609 times in 2012. The overall DWE hits were 860 for 2011 and 1765 for 2012. These hits were not distributed equally over semester, but showed two peaks. The first peak occurred just prior to the first class test. The second peak preceded the final examination held in late June.

Table 1: BlackBoard hits statistics of the WE usage (DWE and SWE on Two Ports)

Year (Enrolment)	2011 (71)		2012 (60)	
WE type	SWE	DWE	SWE	DWE
Overall hits	584	860	609	1765
Just before the class test 1	309	493	378	558
Just before the final examination	207	291	195	760

It should be noted that the number of DWE hits that occurred just prior to the examination in 2011 may be significantly lower than the number of actual viewings of DWE. Although during the bulk of the semester in 2011 DWE could only be streamed from BlackBoard, they also became available for downloading three weeks before the final examination date, hence students who downloaded them and then reviewed them from their saved files could not be recorded as having viewed them more than once. In 2012 students were unable to download DWE and had to stream them directly form BlackBoard. Therefore, the DWE hits recorded for 2012 are likely to be a more accurate representation and indicative of the actual usage of DWE during the exam preparation period in both 2012 and 2011. It should also be noted that the number of SWE hits shown in Table 1 may also be well under the number of actual viewings. Some students might have downloaded the pdf files and then reviewed them from their saved files.

Examination performance

Table 2 presents overall student performance in the final examinations in 2009-12. As anticipated, students' performance in 2009 and 2010 were not statistically significantly different from one another. Nor were there significant differences found between the results of 2011 and 2012 examinations. However, examinations from 2011 and 2012 did record 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 their results were significantly better than students in 2010: t = 4.08, df = 132, p = 0.000. Similarly, students in 2012 out-performed students in 2009: t = 3.04, df = 122, p = 0.003 and their results were significantly better than students in 2010: t = 4.63, df = 121, p = 0.000.

Table 2: Overall students' performance in final examinations (results out of 100) in 2009-12

Year	Enrolment	Mean	Std. Dev.
2009	64	48.3	20.9
2010	63	43.4	19.4
2011	71	59.8	26.0
2012	60	60.9	20.8

Splitting the results by type of knowledge transfer revealed further insight. Students' performances on the isomorphic tasks, requiring near transfer of knowledge, were nearly identical in all four years. These are depicted in Table 3.

Table 3: Students' performance: isomorphic tasks (out of 25)

Year	Mean	Std. Dev.
2009	20.4	5.4
2010	20.5	6.1
2011	20.9	6.1
2012	20.1	4.6

Table 4 presents the results of statistical analysis (independent samples test) of the two pairs of tasks that were not isomorphic with the tasks studied during semester and hence were considered to require far knowledge transfer.

Table 4: Students' performance: non-isomorphic tasks (results out of 25)

	Year	Mean	Std. Dev.	t	df	Sig. (2-t)
Pair 1	2009	3.6	6.7	-5.1	133.0	.000
	2011	11.3	10.1			
Pair 2	2010	9.4	8.0	-4.2	121.0	.000
	2012	15.4	8.0			

In both cases presented in Table 4, a paired problem that was given to students in a year when DWE were available attracted a significantly better mark than the task that was given in a year when DWE was not available.

Discussion and Conclusions

The examination results presented in Table 2 pinpoint that students enrolled in the unit on electronic engineering in 2011 and in 2012 outperformed those enrolled in it in 2009 and 2010. There were two major differences in the experiences of the former and the latter cohorts: (a) students of 2009-10 had 12 more hours of face-to-face tutorials than students of 2011-12; (b) students of 2011-12 had been offered 10 DWE that were not available to the students of 2009-10 (eight of these DWE were closely related to the material examined in the final exam). It is unlikely that the additional tutorial hours could have worsened student examination performance. Therefore, the reason for the better examination performance of the 2011-12 students is likely to relate to the availability of DWE.

Analysis of the access i.e. ‘hits’ statistics for the DWE on Two Ports (see Table 1) reveals that this DWE (14 minutes duration) was on average watched by a student 12 times in 2011 and 29 times in 2012. Moreover, the average number of hits for this DWE during preparation for the final examination for 2011 and 2012 was 4.1 and 12.7 respectively. As mentioned above, the difference in hits during exam preparations in 2011 and 2012 may at least in part be attributed to DWE downloads in 2011, as once downloaded no further reviews of the DWE were recorded on the system, even if the student watched it numerous times. Thus, the 2012 statistics can be considered as indicative of 2011 actual statistics. This conclusion is also supported by student opinions in 2011 described in Belski (2011):

“Students thought that they used… DWE 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)” (Belski, 2011).

In other words, it can be concluded that students of 2012 (and likely of 2011) on average devoted nearly 3 hours each to study the DWE on Two Ports during exam preparation. Further analysis of the hits for the eight DWE that were closely related to the examination problems, revealed that just prior to the examination in 2012 each DWE was on average watched around 700 times. Assuming that the duration of a DWE was 20 minutes, it can be concluded that an ‘average student’ devoted close to 31 hours of study to DWE while preparing for the final examination. Clearly, some students devoted much less time to studying DWE whilst others used DWE more extensively. For example, records show that one student watched (or attempted to watch) the DWE on Two Ports 63 times during exam preparations.

The abovementioned data suggest that the most likely reason for the improved examination performance of students in 2011-12 relates to devoting significant time to study DWE while preparing for the final examination. Interestingly, students’ examination performance presented in Tables 3 and 4 suggest that studying DWE did not impact near transfer, but significantly improved far transfer of knowledge.

In science education, and even more so in engineering education, the ability to teach students in such a way that they will be able to obtain and apply the knowledge they need in an ever-changing and complex workplace is critical. Therefore any strategies that can engage students in learning that enables far knowledge transfer should be identified and utilised to its full capacity. Industries that employ engineering graduates regularly identify problem solving as an essential attribute they require from any new graduate employee. However by ‘problem solving’ they do not simply mean the ability to do calculations and solve mathematical problems, they refer to an ability of graduates to apply the knowledge they learnt at university to new, and complex, real-world problems. This is only possible if significant far knowledge transfer occurred. The use of DWE appears to be a relatively simple, time- and cost- effective strategy that can be utilised to enable far knowledge transfer.

With the help of Camtasia Studio or similar screen recording software, DWE can be recorded on a tablet PC during tutorials and later, in just an hour or so, edited and converted into mp4 format and uploaded for students to access. The DWE that were used in this study were recorded by the author outside of class time. Each DWE took three to five hours to produce. This included planning the lesson, preparing circuit diagrams and other materials, recording the DWE and editing and uploading it.

This study investigated the impact of DWE on knowledge transfer by analysing students' performance in final examinations. Whether the impact of DWE on far knowledge transfer observed in this study was a lasting one, and went beyond examinations, needs further investigation.

It is also important to note the popularity of DWE compared to SWE, with DWE being accessed over 30% more times in 2011compared to SWE, and more than double than SWE in 2012 (where all access was tracked more accurately), suggesting that students found DWE more helpful in engaging in online learning. This observation paired with the significant improvements in examination results for questions requiring far knowledge transfer advocates that DWE should be considered as an extremely worthwhile tool for supporting student learning in the university setting.

To observe significant improvements in student performance in a unit with a concurrent decrease in face-to-face contact hours would be considered surprising by many educators. However this study reveals that the provision of DWE to students, which they could access as need arose, may have contributed to an improvement in their learning and their ability to undertake far knowledge transfer. Hence signalling that providing dynamic educational resources may enable students to engage in the learning process effectively in their own time.

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