Student-Created Dynamic (Video) Worked Examples as a Path to Active Learning

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Structured Abstract

BACKGROUND
Numerous approaches can be utilised to engage students in active learning. One such approach is through engaging them in the creation of teaching materials. Whilst developing instructional materials students are engaged in creating multimodal representations and, therefore, learn new material effectively (Prain & Waldrip, 2006). It has been reported that engaging preservice primary teaching students in creating 'Slowmation' videos on science concepts enabled them to effectively learn these concepts (Hoban & Nielsen, 2013). It has also been reported that studying dynamic (video) worked examples (DWE) not only improved overall examination performance of engineering students (Belski, 2011), but more specifically, significantly improved far transfer of knowledge (Belski & Belski, 2013). Furthermore, it has been repeatedly demonstrated that students invest more time into, and perform better in, assignments and subjects that they enjoy (Pekrun, Goetz, Titz, & Perry, 2002). To date student enjoyment levels of producing DWE has not been reported.

PURPOSE
This paper aims to investigate the effectiveness of learning new course material in disciplines of Science, Technology, Engineering and Mathematics (STEM) by means of engaging students in creating short DWE on topics new to them and assess their enjoyment of the task.

DESIGN/METHOD
Two cohorts of students (4th year undergraduate and postgraduate) enrolled in a unit on advanced circuit simulation with PSpice in two consecutive years were given two weeks to record a 5 to 10 minute DWE on digital electronic circuit simulation. This individual DWE project corresponded to 25% of the unit's total assessment. Although the unit activities covered numerous advanced topics of circuit simulation, no classes were held on digital simulation. It was expected that students would learn digital simulations while preparing and recording their DWE. The first cohort used freely available screen capture software. The second cohort used the Camtasia Studio software. Students were surveyed on their learning and their experiences while creating DWE.

RESULTS
Most of the students enjoyed their experience in DWE creation. They reported that video creation was a valuable learning experience. Many students also expressed their interest in having more video assignments in future. Whilst students reported enjoying the experience overall, students from the first cohort, using freely available software, found the lack of editing options a frustration as it required them to re-record the video numerous times. Students from the second cohort, who used Camtasia Studio software, with appropriate editing functions, did not report any frustration with the recording.

CONCLUSIONS
Developing DWE enabled students to engage in active learning of new skills and to gain new knowledge. Students also reported enjoying the assessment, which has previously been shown to be linked to performance. Considering the increased availability of software that enables students to be engaged in the production of learning resources to benefit themselves and their peers, the authors would recommend for other STEM educators to consider utilising student-produced DWE in their study units - but being careful in making sure suitable editing software is available for students to use.

KEYWORDS
Active learning, Multimodal representation, Dynamic Worked Examples (DWE), Slowmation.

Introduction

Multimodal representations in STEM learning

Many concepts that need to be grasped by students of science, technology, engineering and mathematics (STEM) are quintessentially multifaceted. Scientists and engineers describe natural phenomena and behaviours of artefacts using models and theories. These models and theories usually cannot be adequately grasped in a single 'dimension' and require multiple representations to be understood holistically. For example, in order to fully comprehend the operation of an electronic circuit, a practitioner needs to unify its behaviours in time domain, frequency domain, changing temperature conditions, etc. In nutrition and food science students need to have a clear grasp of the chemical structure and composition of foods and how this will impact on its chemical and physical properties as well as digestion and absorption.

Therefore, to help learners in comprehending concepts holistically, STEM educators deploy multimodal representations of natural phenomena and behaviours of artefacts (Ainsworth, 2008). Textbooks and other STEM learning resources usually contain two or more types of such representations. The latter can be pictorial, textual, mathematical, graphical, behavioural, verbal, etc. These representations usually depict different aspects of the behaviours and complement each other, enhancing the learner's holistic understanding. Traditionally, most of the multimodal learning resources have been developed by educators. Pupils have simply been expected to grasp these representations and to link them together to achieve adequate comprehension of a new topic (Belski, 2008). Recently, science educators posited that students can learn more effectively if and when they develop multimodal representations by themselves (Prain & Waldrip, 2006).

Rapid expansion of free and inexpensive digital technologies that occurred in the past five to ten years, offered educators with the opportunity to engage learners in development of their own representations that are truly multimodal. Waldrip and colleagues, for example, reported on successful learning of science by school children, who created their own representations of physics phenomena using MS PowerPoint (Waldrip, Prain, & Carolan, 2006). Hoban and Nielsen (2013) discovered that creating 'Slowmation' videos facilitated the preservice primary teaching students' learning science concepts. In essence whilst creating 'Slowmation' videos students were engaged in developing multimodal representations of scientific phenomena. Hoban and Nielsen concluded that students, who generated their own Slowmation videos "iteratively revisited the content through the construction of five representations as a cumulative semiotic progression: (i) research notes; (ii) storyboard; (iii) models; (iv) digital photographs; culminating in (v) the narrated animation" (Hoban & Nielsen, 2013, p. 1).

Learning with Dynamic Worked Examples (DWE)

Development of inexpensive and free software products that allow recording videos by capturing a computer screen, have enabled educators to develop learning video resources with tolerable time investment and for a fraction of a cost associated with traditional video production. Many educators have used the Camtasia Studio software to record dynamic (video) worked examples (DWE). In addition to the static information and visual elements that is contained in traditional (static) worked examples, DWE incorporate sound instructions that can be watched over and over again.

It has been reported that DWE enhanced student learning and improved student study satisfaction (Belski, 2011; Belski & Belski, 2013; Patel & Feinson, 2005; Wandel, 2010). Patel and Feinson (2005) reported that video illustrations were (i) effective in engaging students studying statistics in using spreadsheet applications, and (ii) helped students enjoy statistics. Wandel (2010) reported on success of DWE in his classes on thermodynamics. He found that students liked the DWE more than the static snapshots of the videos that were offered as pdf prints. Belski (2011) discovered that students in his class on electronic engineering liked the 10 DWE, that he developed and used them extensively to prepare for the final examination. He also found that these DWE statistically significantly enhanced students' performance in final unit examination (Belski, 2011). Furthermore, Belski and Belski (2013) reported that this statistically significant improvement achieved by students in final examination occurred as a result of the boost in far knowledge transfer.

The abovementioned learning effectiveness of student-generated representations triggered the authors' interest in engaging students to learn by creating their own multimodal representation of new material. The instructional successes of DWE determined the authors' choice – students were expected to develop DWE to learn new material. This paper reports on student perceptions of their learning whilst developing DWE and assesses the impact of this development on student learning and engagement. More specifically, the authors were interested to discover (i) whether students learn new material effectively whilst they produce DWE and (ii) whether DWE development is considered by students as more effective for learning than other unit activities.

Impact of student emotions on learning and performance

Academics in the STEM sector often focus too much attention on delivery of content, and often forget that the student experience and perception of the assessments and subjects are also of critical importance. It has been shown by our colleagues from psychological sciences that academic emotions, including student enjoyment, are significantly related to students' motivation, learning strategies, cognitive resources, self-regulation, and academic achievement (Pekrun et al., 2002). Specifically that students are not only more engaged but also invest more time into, and perform better, in assignments and subjects that they enjoy. Therefore the authors were interested in assessing the whole student experience of undertaking DWE as an assessment task, in term of both their perception of their learning but also of their enjoyment of the process.

Methodology

General setup

To investigate the impact of DWE production on student learning, the authors incorporated the development of DWE into the assessment of a unit on advanced circuit simulation with PSpice in two consecutive years. This unit was offered to postgraduate and undergraduate students in 3rd and 4th years. In 2013, 76 students were involved in individual DWE activities. In 2014, 25 students developed their individual DWE. In both years DWE production activities occurred at the end of the semester.

Both 2013 and 2014 cohorts were engaged in identical weekly class activities that consisted of a 2 hour 'lecture', and 2 hours of laboratory work. The 'lecture' classes were very practical and consisted of three to five activity sessions. Each session started with a five to ten minute introduction of new material that was followed by a practical exercise that occupied 10 to 20 minutes. During these practical exercises students used their own laptops to build and simulate a circuit with given parameters. Laboratory work was conducted in three-week blocks. Each block consisted of a laboratory project and a laboratory test. Each laboratory project was conducted in teams of 2 to 3 students and occupied the first two weeks of the three-week block. It required teams to build and to simulate circuits with the specified parameters. In the last week of the block, students sat individual laboratory tests. Test questions were directly related to the preceding laboratory project.

The authors expected that in the first 10 weeks of semester students will gain adequate skills in advanced PSpice simulations and, therefore, will be fully prepared to learn new material on digital simulations individually. No classes were held on digital simulation. It was expected that students would learn digital simulations whilst preparing and recording their DWE. All students were asked to develop a 5 to 10 minute DWE on digital (undergraduate) or digital-analog (postgraduate) electronic circuit simulation that could be used as a learning resource by other pupils. Students had two weeks to complete the DWE development. They were given full freedom to select a circuit to simulate and the way they organise the content of their DWE. This student-generated DWE corresponded to 25% of the unit's total assessment. The assessment criteria included the correctness of the material, structure of the video, how well the narration suited the video content and the usability of the DWE as an educational resource for other learners.

Why DWE on PSpice?

All students produced DWE that incorporated simulations of behaviours of digital or digital-analog circuits with PSpice. PSpice is a PC version of the SPICE software (Simulated Program with Integrated Circuit Emphasis). SPICE was developed for mainframe computers and has been used by engineers and scientists for nearly 30 years. PSpice allows a practitioner to sketch an electronic circuit and to simulate its behaviours in time, frequency, temperature, etc. Every electronic circuit is simulated and 'refined' with help of PSpice or similar circuit simulator before it can be manufactured.

It was expected that whilst developing DWE on PSpice, students would be truly engaged in active learning. The authors anticipated that students would construct numerous representations whilst (i) deciding on the circuit to simulate, researching this circuit and building it in PSpice; (ii) deciding on the content of the DWE and the way it will be presented and explained to a 'viewer' (e.g. preparing explanatory MS Word or/and PowerPoint slides to be used as adjunct to PSpice recording); (iii) deciding on what PSpice simulations to perform to ensure the DWE completeness; (iv) estimating the expected simulation outcomes (this had to be done by means other than PSpice itself); (v) interpreting the simulation results; (vi) creating a script for the DWE; (vii) editing the recorded DWE.

Screen capture software tools

Students made their own choice of the software to use in order to produce the DWE. There were numerous freely available software tools for capturing videos of a PC screen that could be learnt quickly (e.g. Ezvid, CamStudio, Webinaria). The main drawback of these freely available software tools was a limited or no editing capabilities they offered. Commercially available Camtasia Studio software allowed both to record a PC screen and to edit the recording. Although, a number of university open-access computers had Camtasia Studio installed, most of the students from the 2013 cohort downloaded and deployed free tools to record their DWE. Students from the 2014 class were advised to use the Camtasia Studio software at least for screen capture and editing. To ensure that audio quality was not affected by noise in the open-access computer room, students were advised to record their narration with the freely available software for audio recording (e.g. Audacity) and to embed the recorded audio into their DWE during editing with Camtasia Studio.

Most of the students had never previously created educational videos or been involved in the development of educational materials. Only one student from the 2013 cohort indicated that he had used free screen capture software to record a simple procedural video.

Data collection

The data presented in this paper comes from two sources: (a) student grades for the DWE development and (b) web-based student surveys that were conducted by the authors after the end of each semester.

Experimental Data

Quality of student-generated DWE

Overall the DWE produced by students from both cohorts were of good quality. In both semesters students' videos were assessed by the authors using five identical criteria. The marks for the DWE development did not differ significantly between the two cohorts. The class of 2013 achieved the average of M=17.9/25 (SD=3.6). The class of 2014 got just a little lower average mark: M=16.4/25 (SD=5.2). Eleven DWEs developed by the students of the 2013 cohort and six videos produced by the students of the 2014 class were of very good quality. These videos can be used as sound resources for student learning.

Example of a student's DWE

Figure 1 shows screen prints of two sections from the same student-generated DWE, which incorporated extensive audio explanations covering both the operation of a control system to position a solar panel and a simulation of this control system in PSpice. The control system intended to achieve the highest power generation efficiency of the solar panel.

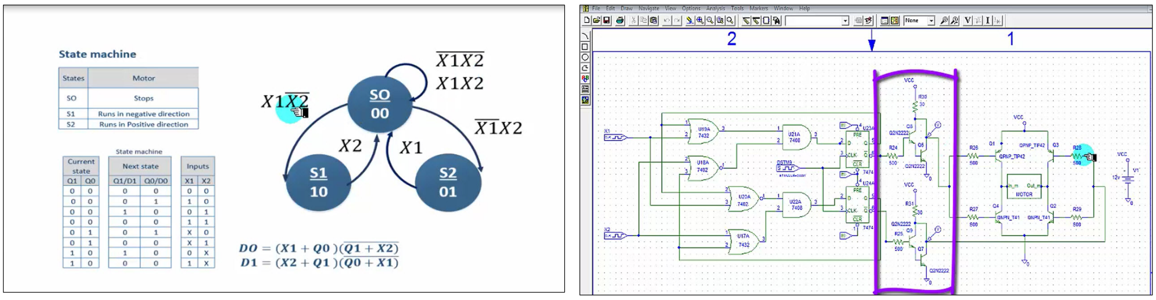

Figure 1: Two screen prints of a student's DWE

The left half of the screen depicts a representation that explains the operation of one of the blocks of the control system. The right half of the screen in Figure 1 shows the representation of the circuit that models the behaviour of the complete control system.

Survey data

Twenty one students from the 2013 cohort and 14 students from the 2014 class completed the survey administered by the authors. Table 1 presents the opinions of students on the development of DWE and on the impact of this development on their learning.

Table 1: Survey responses (Scale: 10 - fully agree, 5 - not sure, 0 - fully disagree)

		2013 (21) Mean (Std. Dev.)	**2014** (14) Mean (Std. Dev.)
Q1	I enjoyed developing PSpice video tutorial	7.52 (2.27)	7.50 (2.10)
Q2	Developing PSpice video tutorial helped me to learn digital simulations very effectively	6.30 (2.16)	7.69 (2.43)
Q3	Developing PSpice video tutorial was much more useful for my learning than the lecture classes	4.47 (2.01)	5.08 (3.34)
Q4	Developing PSpice video tutorial was much more useful for my learning than preparing for PSpice laboratories	4.00 (3.13)	4.06 (2.73)
Q5	Developing PSpice video tutorial was much more useful for my learning than preparing for PSpice laboratory tests	4.53 (2.77)	6.00 (3.44)
Q6	I wish to have more video assignments in my future study	5.68 (3.69)	6.08 (2.47)

Some students' comments provided insights into their learning whilst developing DWE:

I had no clue about how to describe a digital circuit before the video. I watched some tutorial video on YouTube and imitated their description. I tried my best to eliminate errors I made in explaining the [operating] principle of the circuit.

The following is a selection of typical student responses to the survey questions that identify how activities in DWE development impacted on their learning.

Question: What aspects of developing your video were most efficient for your learning?:

In order to explain everything in the video clearly, you need to understand them first. I had to think like a teacher. Researching and gathering all the relevant information. Most efficient learning while developing video was to understand the topic and showing it step wise rather than putting the facts randomly. Using most of the techniques taught in lectures and labs in the project in the given time of less [than] 10 minutes. Doing the research for the topic. Preparing materials to go on the video. Structuring the video.

Question: What aspects of developing your video challenged you the most?:

The narration, the relation between the narration and the image of the video. Organising language to express the idea. To deliver the audience with more information not only on the circuit and simple simulation, but also some extended knowledge. That needs good understanding not only of electronic circuits, PSpice itself and also the ability to think clearly. The most challenging [aspect] in developing the video is to give a precise presentation which will cover all the requirements but also at the same time making it enjoyable to watch. Completing the video within 5 mins was the most challenging. There was so much I wanted to say but could not finish it in 5 min. So at the end had to minimise my video contents.

It is important to note that some student responses to the latter question from the cohort of 2013 identified that they experienced problems that were related to editing their DWE:

Editing the video with the software chosen. [I] spend 90% time on… learning how to record video and editing…! Most challenging part of developing video was to dub [a]n[d] show at the same time.

Students' concern with the editing was later clarified by face-to-face discussions with a smaller group (n=10). It was confirmed that some students chose screen capture software that either did not offer an editing facility or had a poor one. Due to this problem with editing of recordings by free software tools the students of the 2014 class were advised to use Camtasia Studio.

Discussion and Conclusions

The first research question

The first research question, whether students learn new material effectively whilst they produce DWE, can be answered in the affirmative. This conclusion is supported by (i) the good quality of student-generated DWE and the good marks they achieved for the DWE development, by (ii) student written responses that support their engagement in development of multimodal representations, as well as by (iii) student perceptions of their learning whilst producing DWE that are identified by their responses to Questions 1, 2 and 6 in Table 1.

Student marks for the DWE task were in line with their performance in other course activities and averaged in the high credits (65 to 68 out of 100).

Students' written responses presented in the previous section indicate that they were challenged during DWE development and were truly engaged in creating multimodal representations. These responses identify that students researched the topic and made appropriate notes, planned their DWE and created its script, developed appropriate material for their video recording, edited the video and the audio material to make a complete narrated video.

Most of the students from both 2013 and 2014 cohorts enjoyed their experience in developing DWE. The responses of both cohorts to Question 1 in Table 1: *I enjoyed developing PSpice video tutorial* were very nearly the same (2013 Mean=7.52/10; 2014 Mean=7.50/10). Both classes also perceived their leaning whilst developing DWE positively (Question 2 in Table 1: *Developing PSpice video tutorial helped me to learn digital simulations very effectively*; 2013 Mean=6.30/10; 2014 Mean=7.69/10). Comparison of student responses to Questions 1 and 2 in Table 1 reveal similar levels of enjoyment in both cohorts, and noticeable difference in student assessment of effectiveness of DWE development for learning new material. The lesser score assigned to learning gains during DWE production by the 2013 class can be explained by student frustration with the limitations of the freely available screen capture software tools. As it has been mentioned, poor editing facilities of the free software tools, used by most of the students in the 2013 class, required students to record their DWE numerous times in order to ensure that the final DWE would be of acceptable quality. This resulted in additional time investment, and has likely led to some negativity in the 2013 class' perception of their learning gains whilst producing DWE. Students' responses to Question 2 in Table 1 hint that these negative perceptions disappeared in 2014 because students used Camtasia Studio to record and to edit their DWE.

The finding that students appear to be interested in engaging in more video assignments in future further supports the conclusions relating to the first research question (Question 6 in Table 1: *I wish to have more video assignments in my future study;* 2013 Mean=5.68/10; 2014 Mean=6.08/10). Interestingly, students' enthusiasm to engage in more video assignments was statistically significantly more modest than their enjoyment of the development of DWE that is revealed by their responses to Question 1 in Table 1 ($t=4.6$, $p<0.001$). This significant difference in student perceptions may indicate that, although they have learnt effectively whilst developing DWE, the DWE production consumed too much of their time and effort. This interpretation of the statistically significant difference between enjoyment of DWE creation and willingness to engage in more video assignments in future may explain student opinions on how DWE development compared to other unit learning activities.

The second research question

The answer to the second research question, whether DWE development is considered by students as more effective for learning than other unit activities, is not entirely clear and needs further investigation.

As revealed by Questions 3 and 5 in Table 1, students assessed the impact of the DWE development on their learning as matching both knowledge acquisition at lecture classes and learning during preparation for laboratory tests: *Developing PSpice video tutorial was much more useful for my learning than the lecture classes*; 2013 Mean=4.47/10; 2014 Mean=5.08/10; *Developing PSpice video tutorial was much more useful for my learning than preparing for PSpice laboratory tests*; 2013 Mean=4.53/10; 2014 Mean=6.00/10. The distribution of individual student responses to Questions 3 and 5 in Table 1 showed a significant division in student opinions. Twenty one percent of students in the 2013 cohort assessed DWE development as more useful than lectures; 42% – less useful, the rest (37%) were undecided. Students in the 2014 class were more positive to DWE: half of them favoured DWE over lectures, 21% – preferred lectures, the rest (29%) were undecided. Similarly, 18% of the 2013 students found DWE development more useful than preparation for laboratory tests, 59% favoured the latter and 23% of them were unsure. The 2014 cohort was more positive. Fifty five percent of them assessed DWE production as better learning than studying for laboratory tests, 36% preferred the latter to the former, 9% of students were undecided.

Student opinions on DWE development versus laboratory preparatory work clearly favoured the latter (*Developing PSpice video tutorial was much more useful for my learning than preparing for PSpice laboratories*; 2013 Mean=4.00/10; 2014 Mean=4.06/10). More than two thirds of students from both cohorts found laboratory preparations more useful to their learning than DWE production.

Conclusion

DWE production enabled students to gain new knowledge through the development of multimodal representations. Although all students reported learning effectively whilst working on their DWE, students in the 2013 class were less certain of their gains than the students in the 2014 cohort. This difference was most likely triggered by the lack of editing options offered by the freely available screen capture software used by most student in 2013, which led to repeated re-recording of their DWE and waster precious time. Most students also reported enjoying the assessment task, and as it has previously been demonstrated that students perform better and invest more time into assignments and subjects that they enjoy (Pekrun et al., 2002), this is an important consideration. In view of this student enjoyment, paired with the increased availability of software that enables students to be engaged in the production of learning resources to benefit themselves and their peers, the authors would recommend for other STEM educators to consider utilising student-produced DWE in their study units - but being careful in making sure suitable editing software is available for students to use.

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