DEVELOPING DIGITAL WORKED EXAMPLES TO EFFICIENTLY DEVELOP PROCEDURAL KNOWLEDGE

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Abstract

Universities in Australia, responding to reduced government support, are changing rapidly in efforts to increase efficiency. At the institutional level this includes increasing staff workloads, decreasing face-to-face contact, and greater reliance on sessional staff members. At the same time, the student cohort face financial pressures that often require a balance between work and education. These macro-level changes have put pressure at the ‘coal face’ as educators are called upon to adapt their teaching methods. Blended learning has been advanced as a means of achieving both cost savings and increased learning effectiveness [1,2].

This study provides a personal account of a group of accounting academics (content specialists) who have responded to institutional pressures by becoming ad hoc instructional designers. These challenges may resonate with many other academics. Without specialist training in educational technology, many academics are being called upon to develop learning materials to support their university’s commitment to Blended Learning. We also consider the wealth of materials already made available online by other academics, and the relative benefits of production versus referring students to existing resources.

For academics who choose to develop their own Digital Learning Objects (DLOs), Cognitive Load Theory (CLT) [3,4] provides insights and guidance. Specifically, worked examples [5,6,7] provide an efficient way to develop procedural knowledge [8] that can be efficiently and effectively distributed as DLOs. Videos that explain and illustrate the problem-solving steps in fundamental accounting problems offer an alternative, or at least a supplement, to individual consultation. Student feedback has been positive, and the pattern of student access to on-line materials suggests that they are particularly useful for just-in-time learning. Our experience also suggests that, despite a significant initial investment of time, there are significant time savings to be achieved by the educator.

Keywords: Digital Learning Objects, Cognitive Load Theory, Procedural Knowledge.

1 INTRODUCTION

The changing tertiary education landscape is creating and amplifying the challenge for educators, as well as providing new opportunities for efficiently reaching students in more engaging ways. Discipline experts, some of whom commenced their careers pre-PowerPoint, are now being expected to connect with students in new ways. Understanding the relative strengths, and weaknesses, of alternative mediums of instruction is important when matching them to learning objectives [9,10,11].

In addition to conveying facts and definitions (declarative knowledge), and developing an understanding of concepts and the relationships between them (conceptual knowledge) [12], procedural knowledge, i.e., the “action sequences for solving problems” [12,13] is fundamental to accounting. Worked examples have been identified as a powerful way to facilitate the acquisition of procedural knowledge [14,15]. This paper describes the use of Digital Learning Objects (DLOs) to distribute worked examples to students for Just in Time (JIT) access and learning. Such worked examples are widely available on the internet as discipline experts turn to this medium for connecting with a huge audience (well beyond their students). Cognitive Load Theory (CLT) is used to guide design choices in the development of these DLOs.

Cognitive Load Theory offers motivation and guidance for the development of worked examples to support the acquisition of procedural knowledge. Mostyn [16] called for further research in accounting to explore the insights from CLT and this paper responds to that call. Our findings highlight the efficiency and effectiveness gains for both students and educators from providing worked examples in the form of DLOs. Based on the experience of discipline, rather than instructional design, experts this paper seeks to provide practical insights for other accounting academics.
From our experience we suggest that the investment in developing worked examples, particularly in the form of DLOs that can be distributed and stored electronically, provides a useful supplement to existing learning materials. Although it requires an initial investment to become familiar with the tools and to create DLOs, the return on that time can be significant. The tools are intuitive and the learning materials can be distributed widely and reused over numerous years, thereby reducing future demands on the educator’s time while continuing to create some level of personal connection with students and supporting the learning process on a Just in Time (JIT) basis. We argue that the purpose of these DLOs is to supplement, rather than replace, the instruction received in lectures and tutorials. Other academics, facing increasing time pressures, disengaged and absent students, and changing institutional expectations may relate to these changes in the educational environment and benefit from our experience.

The following sections describe the changing educational context that motivated the development of these DLOs. A specific educational context, a management accounting course, is described to explain the incremental benefit that DLOs can have for the acquisition of procedural knowledge. This is followed by a discussion of the insights that Cognitive Load Theory provides for the creation or evaluation of DLOs. Student feedback then illustrates the benefits for students. Finally, the paper makes recommendations to accounting academics considering developing DLOs.

2 CHANGING TERTIARY EDUCATION ENVIRONMENT

The tertiary education environment has been changing rapidly. Changes in government funding in Australia have led to an efficiency imperative. In our experience over the past 25 years we have noted larger class sizes and an increased reliance on sessional tutors. These changes have decreased our, as course coordinator’s, direct interaction with students and motivated our interest in finding new ways to connect and educate that we believe will be of interest to other educators.

Concurrent with increasing demands on the course coordinator have been the development of new resources. For example, the internet as a means of connecting with students in the form of web-based content delivery systems, such as Blackboard or Moodle. Related to this has been the proliferation of digital technologies for the creation of learning objects (such as recorded lectures, new features in PowerPoint, whiteboard animation, and screen capture) that can be distributed via the internet. Blended learning is a term that has been used for the multi-modal approach to education in which these digital learning objects are provided to augment, rather than replace, traditional lectures and tutorials.

These new forms of delivery and interaction offer great opportunities for educators, but choosing appropriate tools and acquiring the necessary expertise can be daunting. There is an expectation that educators will be digitally literate in order to create these learning objects. Perhaps more important than digital literacy, however, is an understanding of the learning principles that guide the development of effective learning materials. As discipline experts, rather than instructional design experts, practical guidance is necessary to navigate this rapidly changing instructional landscape.

2.1 Changes in student characteristics

In addition to changes in the institutional environment we have noted changes in the student cohort at our regional university. Attendance at lectures and tutorials has been declining. Whether it be because of increased financial pressures leading to more hours working, or a general shift in priorities, or the availability of alternatives, it has impacted on the level of connection between educator and student.

In research that extends beyond the scope of this paper, and which is yet to be reported, a survey of 56 of our Bachelor of Commerce students found that convenience: easy to access, download, attend (scoring 4.61/5.00); effective for revision: when revising prior to the exam (4.64/5.00); concise: focuses on key issues (4.50/5.00); and efficient: the learning was high compared to the time spent (4.43/5.00) were the most important criteria for learning materials (compared to 3.11/5.00 for sociability: being able to work with other students). These results support our perception that students are increasingly taking an instrumental approach.

3 THE LEARNING CONTEXT – A MANAGEMENT ACCOUNTING COURSE

The following description of the learning context provides the basis for considering how DLOs can be integrated into existing learning resources. Students from two courses (Management Accounting and
Business Finance) were provided with videos to illustrate key calculations. The management accounting course will be used to illustrate the typical learning environment.

In the management accounting course students cover 12 topics over 13 weeks. Although there is some relationship between topics (they predominate dealing with procedures - different approaches to costing products and services), they are, for all intents and purposes, separate topics. This creates a challenge for students to rapidly master a set of costing procedures within a two week period. A new topic is introduced in each week’s lecture, and then completed in tutorials in the following week. Students have access to various resources and are advised to use them as follows.

Prior to attending the lecture, students are encouraged to read the relevant chapter in the textbook. Both textbook and lecture explain the purpose, context, and interpretation of the calculations, however the focus of the assessment is on the procedural knowledge necessary to correctly calculate key figures, such as product cost. Lectures illustrate the calculations and provide an opportunity for guided practice as students work through a question with the lecturer. These two hour lectures are recorded and students are able to access them on demand through the course’s Blackboard site (Web-based content management system).

In the week following the lecture, students are expected to complete homework questions from the textbook prior to attending their tutorial. They have solutions (completed calculations, but without explanation of the calculation steps) for these homework questions. Homework and tutorials focus on reinforcing procedural knowledge through practice. Questions generally all take a similar form, with minor changes in context and presentation. In the tutorials students discuss any problems they had with the homework questions, any theory involved in the topic, and then work through past exam questions – individually and then as a class. Or at least, that is the recommended study procedure.

Although some students appear to follow the recommended study procedure, anecdotal feedback suggests that, of the students who attend lectures, 40-60% come with no prior exposure to the topic. Some view the lectures on-line in the same week that they are delivered. Less than 30% of the 60% who attend tutorials (a rough approximation based on feedback from tutors) complete the homework prior to the tutorial. Immediately prior to the final examination period, and after assignments across their various courses have been submitted, students begin to prepare for the examination. Three topics are assessed in a midsession examination leaving nine topics assessed in the final, 2 hour examination. The examination typically includes 40% declarative (facts and definitions) and conceptual knowledge (application of theory) questions. The remaining 60% comprises procedural knowledge (mostly calculations). Students, even those who have been completing the homework and attending lectures and tutorials, find it challenging to master this volume of knowledge in the relatively short space of time. Furthermore, assignments in any of the four courses that a full-time student is concurrently taking often take precedence over regular topic mastery.

Overwhelmed, or side-tracked, students often face a significant challenge when trying to initially acquire, or remaster, the necessary procedural knowledge immediately prior to the examination. Five minutes of explanation, provided at the right time, can save many more minutes/ hours of misdirected effort. Providing this explanation becomes onerous for the academic, however, since it is often after tutorials have ceased, and the examinations loom, that many students recognise the need to return to mastering these calculations. Consultation times rapidly fill, but many students still miss out either because they are embarrassed to seek help, or because it is inconvenient or unavailable at the times they seek it. The recorded lectures are still available for review but are not the most efficient means of acquiring procedural knowledge once the student has attained an initial understanding and needs to master the procedures through extensive and repeated practice. Hopefully, however, students can focus on the specific areas that they personally struggle with. These factors create the demand for focused resources that can be accessed anywhere, at any time. Although it might be argued that students need to be trained to manage their time more effectively, and that pandering to them is not in their long-term interests, it is our experience and contention that developing DLOs to provide short, focused worked examples offer an additional learning resource that is efficient and effective for both lecturer and student.

4 THEORETICAL INSIGHTS

The distinction between declarative, conceptual, and procedural knowledge is useful for academics because these learning objectives can be facilitated in different ways. Declarative knowledge is the acquisition of facts and definitions. An important aspect of declarative knowledge is that these facts
and definitions can be acquired as discrete items. The combination of these facts and definitions, their relationships to each other and the individual's other knowledge structures, forms the basis of conceptual knowledge. In many disciplines, including accounting, procedural knowledge is also very important, that is the steps by which the solution to a problem is determined. In accounting this usually involves calculations.

Although these different forms of knowledge can be distinguished, they are also highly related. Generally, however, it is agreed that at least some level of declarative knowledge is an important precursor to facilitate the communication that leads to the acquisition of procedural and conceptual knowledge. In most cases the acquisition of each form of knowledge might be seen as an iterative process. A basic understanding of the common language of the discipline facilitates the interpretation of new information that builds and forms relationships (schemas) that then allow a more sophistication compilation of facts and definitions that subsequently facilitate the acquisition of more complex schema. This understanding of the language of the domain, and the relationships between concepts, is also important in understanding the procedures necessary to solve problems and, importantly, to be able to identify the most appropriate procedure given the problem, and apply principles learned in one procedure to learning another (transference).

Consider a specific management accounting procedure, such as process costing. An understanding of the physical and organisational aspects that determine the appropriateness of this costing technique are important in understanding the steps in its application (i.e., procedural knowledge). Therefore, the development of declarative and conceptual knowledge is crucial. Assigned textbook chapters, and the discussion in lectures and tutorials, are intended to develop the initial declarative knowledge and provide the basis for the ongoing development of conceptual knowledge [17]. Although the focus of this paper is on the development of procedural knowledge, it is important to note these relationships between declarative, conceptual, and procedural knowledge. Furthermore, the importance of declarative and conceptual knowledge in the acquisition of procedural knowledge emphasises the crucial role that lectures and tutorials have. The worked examples described in this paper are not a substitute for lectures and tutorials [18], they are a supplement that we argue can be particularly effective in the acquisition of procedural knowledge.

An important characteristic of procedural knowledge in accounting, as illustrated in the calculation of process costs, is that the steps are the same (although the nuances of their application sometimes differ). Mastery of these procedures often requires repetitive practice. Therefore, the most effective, and efficient, means of facilitating the acquisition of procedural knowledge may differ to declarative or conceptual knowledge in important ways. This paper will focus on the acquisition of procedural knowledge – a discussion of the acquisition of declarative and conceptual knowledge is beyond the scope of this paper.

Wynder and Luckett [14,15] consider the acquisition of procedural knowledge, and particularly the relative benefits of understanding rules and worked examples. Cognitive Load Theory (CLT) provides the basis for considering the advantages of providing initial guidance, in the form of a worked example, in order to efficiently develop procedural knowledge (in contrast to a Problem Based Learning approach in which students are expected to discover the steps to solving the problem) [9,10,11,19].

### 4.1 Cognitive Load Theory

Cognitive Load Theory was developed by Chandler and Sweller [3,4] and has flourished into a significant literature detailing an increasingly sophisticated theory. While much attention has been directed toward defining and measuring the theoretical constructs [e.g., 20,21], this paper focuses on the general message and insights that the theory offers for discipline experts put in the position of developing instructional materials, specifically DLOs.

Cognitive Load Theory recognises the learner's limited cognitive resources, particularly in terms of their working memory [22,23,24]. This emphasises the importance of designing resources and learning experiences to efficiently use those limited resources. When new stimuli are effectively processed in working memory they are integrated into schemas that are held in the relatively unconstrained long-term memory. Cognitive Load Theory distinguishes between three different cognitive loads that put demands on working memory.

Germane load is beneficial and it is the integration of new stimuli into existing schema, thereby developing a more extensive understanding of the domain in question [25]. Stimuli may, however,
place demands on an individual’s working memory without contributing to their understanding. This might be considered irrelevant or distracting information, it is called extraneous load and instructional designers need to be careful to limit such stimuli because it ties-up the student’s limited working memory, thereby reducing the resources that can be devoted to germane load.

Another form of load is the complexity of the new stimuli relative to the individual’s existing schema, i.e., understanding. This notion of intrinsic load is important because it highlights the importance of instruction that recognises the individual’s unique level of understanding. It also highlights the benefits of worked examples, which develop procedural knowledge step-by-step, thereby avoiding overwhelming the student with stimuli that they are unable to integrate. It also highlights one of the potential benefits of DLOs, that they can be focussed on a very specific procedure, and be accessed when the student perceives the need.

Furthermore, DLOs can be particularly effective because they can incorporate both audio and video stimuli. As will be discussed further, this Modality Effect (see Figure 1) more effectively utilises the limited cognitive resources because audio and visual stimuli are processed in different parts of the brain.

Digital Learning Objects that comprise audio and visual stimuli, and which provide a worked example, can be distinguished from other resources, such as lectures, tutorials, and homework solutions. Note that each of these resources has its own strengths, the focus here is on the incremental benefit of DLOs. Lectures present a large amount of information in a relatively short period of time. Students can be overwhelmed, when Intrinsic Load is too high, because the stimuli is too far beyond the individual’s existing understanding. In contrast, a DLO can be repeatedly accessed by the student when they recognise their need, and are at a level of understanding that allows them to integrate the new information. Similarly, tutorials must meet the needs of a group of students, which may or may not be the most appropriate level for each individual student. Homework solutions can be accessed on demand but are typically presented as outcome feedback, i.e., key answers. If the process is not understood, outcome feedback may be ineffective in learning [27].

5 DIGITAL LEARNING OBJECTS

Figure 2 provides an example of a DLO that was developed to facilitate the acquisition of procedural knowledge, specifically process costing. The DLO demonstrates progressive completion of a product costing problem. As the form is completed in Microsoft Word, the tool, in this case Ink2Go, captures the screen and an audio explanation is given for each step as it is being completed. Highlighting is also used to draw the student’s attention to particular words and/or figures when reiterating the importance of certain steps or explaining the significance of certain outcomes. Although written input can also made with a stylus or mouse (see Figure 3), typing was chosen to avoid dealing with unclear handwriting (extraneous load).
Both DLOs (the one we created, and the DLO that was already available, figures 2 and 3) were available to students on YouTube. Note that both focus on a single calculation and are relatively short (10:44 minutes and 12:19 minutes, respectively). The DLO that was already available had been available for many years and had proven popular (86,245 views, 289 likes). We could have simply directed students to the existing resource. A search in April 2017 revealed over 400 videos directly related to teaching Process Costing. Some individual videos had hundreds of thousands of views over many years, while the total views across all of the videos easily exceeded a million. For the academic considering investing in the skills necessary to develop their own DLOs there are, however, a number of benefits from authoring DLOs, rather than simply referring students to existing DLOs.

Creating the DLO took less than 30 minutes (preparation and recording with some pauses). It is one in a series of DLOs that were developed to provide a worked example for each of the procedures/calculations that were fundamental to the management accounting course. The process of developing the DLO lead us to insights that improved our ability to facilitate the acquisition of procedural knowledge. The benefits of developing rather than referring to existing DLOs also include:

- Students feel more confident that the DLO is relevant and answers the question in the way that is expected by the educator.
- The DLO can be tailored to respond to the most common problems that the students in the course are having.
- A consistent approach can be taken. This reduces extraneous load, the student can focus on the important stimuli rather than irrelevant differences in format or style.
- Attention can be given to design choices that will increase the effectiveness of the DLO.
• Students who request help with a particular procedure, or step within a procedure, can be referred to a DLO. Our experience is that email enquiries around exam times often require a very repetitive response. Being able to provide a link to the DLO is efficient, but maintains a sense of personal response to the student’s problem.

• The process of developing and publishing the DLOs can be intrinsically motivating, as a creative process, and rewarding (through feedback from YouTube analytics).

• The suite of DLOs can be built, and refined, over time and across related course offerings. This ‘reusability’ greatly increases the return on the educator’s time in developing the resource.

In developing the DLOs we proceeded through the following steps.

5.1 Steps in developing a DLO

1. Identify a discrete procedure that can be illustrated in 5-10 minutes. A ‘bite-sized’ chunk can focus on essential processing, avoiding extraneous load.

2. Eliminate distracting stimuli – have a form that can be completed by inputting key figures.

3. Provide students with the form so they can focus their attention on the calculation of the key figures rather than the format, also avoiding extraneous load. This also encourages the student to work through the steps, rather than just observing them.

4. Before beginning the recording process, practice the task first, including articulating the steps (thinking through the steps is not the same as explaining them). Making notes can improving the flow and make sure that important points of explanation are not missed.

5. There will always be room for improvement in presentation, re-recording again and again to eliminate pauses etc. Although mistakes in calculations, or explanations, should not be released, our students were more concerned about getting the resource than the professionalism of its production.

6 REFLECTIONS ON EXPERIENCE

The biggest impediment to our foray into creating DLOs was the concern that they would not be professional enough. A quick review of the learning resources that are available on Youtube, and which are very popular, indicated that a professional production was not necessary. This view was supported by a survey of 56 undergraduate management accounting students. They ranked Professionally Presented as 4.18/5.00, which compared to Convenience that they ranked 4.64/5.00. This, combined with the range of available software and minimal hardware requirements, means that self-production is within easy reach of most academics. The range of instructional videos freely available on YouTube gives an indication of the ease and attraction of such self-production. These videos were produced with a wide variety of tools including video recordings of lectures, screen capture, and whiteboard animations.

Why produce another video when videos already exist and the procedures are relatively standardised? Although there may be many benefits, as previously discussed, perhaps the perceived need to produce an apparently redundant video is ego, seeking hits and likes. Authors may also compete in this space for financial benefit (although humorous feline behaviour is more likely to generate interest from a broader community with the consequent YouTube revenue). However, many of the YouTube authors choose to upload their videos without advertising and so we prefer to see the publication of DLOs as a philanthropic contribution to providing educational resources with the gratification of reaching a wide audience.

Reviewing the resources that are available on YouTube, and the reaction to them, reveals interesting insights that can guide the development of DLOs. For example, a review of the comments made on one of the most popular (at least in terms of the sum of hits) reveals some of the benefits to students. The following comments were made on a screen capture worked example provided by Education Unlocked (34282 subscribers), first published 11/11/14, with 83038 views as at 2/04/17 (see figure 2) the video had received 238 likes, 8 dislikes, and 35 comments. Although it is noted that 35 comments from 83038 views presents a risk that the comments are not representative of the majority of viewers, their comments provide insights as to the perceived benefits of the worked example.

Some indicated that the video addressed a deficiency in the explanation of their professor:
“This was explained far better than the person that’s supposed to be my professor. In a few minutes you explained what took him well over an hour to do and you conveyed these concepts far better. This was very helpful. Thank you for posting this.”

“you explain better than my lecture! thankyou, Sir!”

“Hey just found this video, great job on it. My prof has nothing on this, thanks a ton for the help!”

“thanks that really helped you make it look so simple”

The relative efficiency of DLOs was also noted:

“This would have taken half an hour to figure out from my textbook”,

“Just wanted to thank you, I have been watching your videos to help get me through class. It is easy stuff to understand, but the book they want us to buy is over $600 … So I’ve been watching your videos instead of reading chapters.”

“I literally never comment on youtube, don’t know why. But this video was fantastic!! Sooooo much simpler to understand you than my textbook.”

“I dislike only one thing about your videos. It looks so clear and simple. Later I’m going to my exercises and it’s chaos again.”

The JIT feature of videos available online is captured but the comment:

“Clearly Explained…Thanks for being my savior for the quiz tomorrow:)”

The JIT use of the DLOs that we developed was also evidenced in the access to the YouTube video immediately prior to the examination (see Figure 4).

![Figure 4 JIT use of DLO.](image)

Some comments also provided the authors with positive feedback:

“This is the best explanation of weighted average cost I have seen on YouTube. Thank you!”

“Very helpful! Thank you for putting your time into making this.”

“I love you”

“Du bist lustig, Danke”

“Thank you! You just saved me! I couldn’t get it before, makes so much sense now.”

“you just saved my life! I don’t know why I could not figure this out before”

“You should consider writing a book, you make it look easy. I’m sure your viewers wouldn’t mind helping you fund it. I wouldn’t! Great job!!”
7 CONCLUSIONS AND RECOMMENDATIONS

The acquisition of procedural knowledge requires practice, after having acquired the necessary level of declarative knowledge to understand the instruction being given. Worked examples provide an effective means of guiding students through the required steps until they develop a level of mastery that allows them to learn from outcome feedback. Therefore, providing worked examples is part of a suite of resources that can be used to facilitate the acquisition of declarative, conceptual, and procedural knowledge. The focus in this paper has been on procedural knowledge, but it is important to remain aware of the interdependencies between, and importance of each of these three forms of knowledge.

The importance of worked examples in the acquisition of procedural knowledge, and guidance that is appropriate for the level of understanding, can be understood by CLT. Cognitive Load Theory also provides guidance for the development of DLOs. A key benefit of DLOs is explained by the Modality Effect, which is that the simultaneous provision of audio and visual stimuli can effectively utilise the individual’s limited cognitive resources. Recognising the limitations of working memory also highlights the importance of avoiding extraneous load (i.e., distracting irrelevant stimuli) and of building understanding progressively to avoid overwhelming intrinsic load (complexity relative to the individual’s existing level of understanding).

A further benefit of DLOs is that they can be distributed electronically, such as in the form of YouTube videos. The videos can then be accessed at times and in places most convenient to the student. This facilitates Just in Time learning. It can also reduce the demands placed on the educator for last minute consultation. In addition to the efficient use of the educator’s time, producing DLOs can be an intrinsically motivating creative process with an added sense of accomplishment that comes from supporting learning, whether it be in the author’s students or others.

The educational environment has seen significant change, and is likely to see further change. A significant part of this change is the availability, and increased reliance on new technologies for interacting with students. Although we believe that there continues to be an important role for the lecture and tutorial, educators need an awareness of the potential benefits of new technologies. However, with the use of these new technologies comes a need to understand some of the basic principles of instructional design. Cognitive Load Theory provides some important insights that can guide discipline experts seeking to develop additional resources for their students.

We found it easy and relatively time efficient to create our resources, versus referring students to existing resources that are already available on the internet. That is not to say that our resources were professionally produced or even polished. Our amateur efforts were, however, utilised by our students and the feedback has been overwhelmingly positive. Our advice to other academics, therefore, would be to just do it!, and to enjoy the learning experience.

ACKNOWLEDGEMENTS

This research was supported by a Teaching and Learning Grant from the University of the Sunshine Coast.

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