USING BUILDING BLOCKS TO CONSTRUCT EFFECTIVE LEARNING OBJECTS

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Abstract

Technological developments over the past decade have had a strong impact on education bringing significant opportunities for changing teaching models. This has led to an interest in the development of shareable, scalable and reusable learning objects. This paper builds on the ideas of Parrish (2004) and other recognised theorists in this area who suggest that the production of educational materials needs to promote adaptive learning strategies. We broaden Parrish's work by testing some of his propositions for object oriented instructional design in the domain of information systems. The contribution of this paper is an extended set of principles for creating multimedia building blocks and aggregating them into learning objects as well as engaging students in the development process. The principles can be used for creating and reusing multimedia building blocks for teaching in many discipline areas. We illustrate the use of these principles by developing and testing a set of learning objects for learning programming. We find that the high cost of creating learning objects noted by Parrish can be ameliorated by using readily available software and Web 2.0 technologies. This approach supports academics developing learning objects without involving professional educational designers and without the added overhead of learning complex software packages.

Keywords: Learning object, Building blocks, Learning programming concepts, Web 2.0 tools, Instructional design.

1 INTRODUCTION

Fast technological developments and new Web 2.0 tools have provided opportunities for the advancement of educational technology that have had a strong impact on teaching styles as well as students' expectations of exciting and challenging learning environments. The development of digital materials provides opportunities for sharing and reuse of teaching resources. However, educators look for ways of modifying or updating existing materials without significant increase in their workload while still catering for individual teaching approaches and learning styles. Learning objects, which we discuss in detail and define in the section below, could be the answer to this problem. Learning objects have been proposed as a method for creating reusable items that academics in many disciplines can share while reducing the burden of having to create them individually.

This paper examines how learning objects can be adapted as a solution for teaching programming concepts. The majority of publications on teaching introductory programming concepts suggest that students experience difficulties learning the concepts and academics find teaching programming concepts to novices challenging (Bennedsen et al. 2008; Matthews et al. 2009; Stone & Clark 2011). Over time more creative teaching approaches have evolved and technological developments have been applied, however difficulties remain for both teachers and novice students (Hadjerrouit 2008; Spronken-Smith & Harland 2009). Many students experience difficulties in understanding what is happening in computer memory during program execution (Milne & Rowe 2004). Therefore this example of a learning problem was targeted in our work on creating learning objects.

Customisation and reuse have been central concepts in object-oriented (OO) software development. Since an *object* is a central concept of this discipline, many lessons learnt in OO design and implementation could be transferred to the design of digital learning objects (Boyle 2003; Douglas 2001; Parrish 2004). These lessons provided general strategies for creating learning objects, however they were not concrete principles for design.

In this paper our contribution is to build on Parish's general propositions for creating object oriented instructional design. We synthesise previously developed guidelines for designing learning objects and object-oriented instructional design into a set of principles for creating and aggregating multimedia building blocks into learning objects. We then augment these guidelines based on the result of our experimental work. In doing this we follow established methodologies relevant to the study of learning objects (Boyle 2003; Cameron & Bennett 2010) using classroom observation, student work and student focus groups and interviews. We also involved students in the creation of learning objects using multimedia building blocks with evidence of an improved learning experience.

2 WHAT IS A LEARNING OBJECT?

Digital or non-digital learning objects have been used as teaching resources for many years. There are numerous definitions as well as multiple names for "learning objects", e.g. reusable learning objects, knowledge object, learning component, information object (Cisco Systems 1999). The focus of definitions of learning objects varies in emphasis from learning to reusability. For example, according to Downes (2003) "… an object is a learning object if it is used in learning. No other criteria apply." A similar rather general definition is provided by McGreal (2004) who includes "educational resources that can be employed in technology-supported learning". L'Allier (1997) takes a more specific approach by defining a learning object "as the smallest independent structural experience that contains an objective, a learning activity and an assessment". Nash (2005) and Ally (2004) expect learning objects to be aligned with specific learning outcomes.

At the same time there are multiple definitions of learning objects that focus on their reusability. The IEEE Learning Technology Standards Committee (2002) defined a learning object as “any entity, digital or non-digital, which can be used, reused or referenced during technology supported learning”. Others emphasise reusability and adaptability “to suit different learning contexts” (Cameron & Bennett 2010, p.897) or stress the ability to integrate a learning object into other courses as part of the definition (Douglas 2001).

Given that there is no one widely accepted definition of a learning object, many researchers suggest features that *should* be inherent in learning objects. For example, in addition to reusability, Gibbons et al. (2002) list adaptability, scalability and generativity. Adaptability is considered from the perspective of a learning individual. That is, students with various levels of ability should be able to adapt instructions based on their specific needs. Scalability covers the extension of learning objects to larger audiences and to higher production levels without a significant increase in cost. Generativity is referred to as aggregation or assembling of composite objects from more basic ones (Liber 2005).

Parrish examined this “struggle toward a definition” (Parrish 2004, p.52) and proposed a “process or strategy” perspective which he named object-oriented instructional design. He also provided a number of propositions for future practitioners for the design of learning objects as elements of an object-oriented instructional design set, although he did not implement these ideas himself. Parrish recommended that learning objects be seen in the context of a larger learning environment, that they should be designed as modifiable, with the possibility of being “interrupt(ed) and annotate(ed)” (ibid, p.62) by educators and should be more than “simply a library for students and instructors” (p.62). Parrish was critical about focusing on the scalability and adaptability of learning objects over the need to place them in a student centred context which is not always “one-size fits all”.

Wiley (2009) classifies learning objects into three categories: content, strategy, and discourse objects. Content objects are simply “self-contained chunks of information” (p. 353); to use them the instructor is expected to create “contextual scaffolds” making them part of educational activities. Strategy objects are defined as instructional “procedures, processes, and patterns” (p. 357) which is similar to Parrish’s approach. Since Web 2.0 and its support for web-based applications including social networking is inherent part of student life, Wiley suggested the third category of learning objects - discourse objects which are a “special class of strategy objects that scaffold interactions among learners” (p. 360), these objects provide infrastructure to facilitate collaboration, such as discussion groups.

In summary, for the purpose of this paper, we accept the general definition of a learning object as “an object used for learning” and we will focus only on learning objects from the content category. However, we propose that in order to provide a definition that can be used to help build a useable tool that is customisable to the needs of individual learners, we support a finer grained definition which includes the additional features of reusability, adaptability, scalability and generativity.

3 BUILDING BLOCKS AS COMPONENTS OF LEARNING OBJECTS

In proposing this definition of a learning object we highlight a possible difficulty identified in the literature: that learning objects could become quite complex in scope in terms of content and development, since they could “take such forms as Web pages, pdf documents, database applications, animations, Java applets, PowerPoint presentations and Quicktime movies” (Oliver 2001, p.454). The problem lies in the fact that granularity has a major effect on the reusability of learning objects (Polsani 2003). The action of extracting a learning object from one topic or course and inserting it into another is not straightforward; learning objects are frequently not suitable for reuse *as is* but require significant modifications. Aiming for smaller reusable objects often results in decontextualisation of learning objects (D. Wiley et al. 2004). However, in our work we found that this is not an issue when re-using smaller components within the similar context, i.e. within the same topic (even across subjects). Decomposing learning objects into smaller components allowed us to take full advantage of the benefits they could offer. We call these components *building blocks*. In doing this we build on Boyle's work which advocated "compound learning objects" and suggested that simpler objects could be "pedagogically unexciting" (Boyle 2003, p.50). However, Boyle acknowledged that simplicity could be valuable for recombination and reuse. This approach toward reuse in multiple contexts is also emphasised in object oriented software development (Booch 1994) as well as in what Parish called object-oriented instructional design (OOID) (Parrish 2004).

Since learning objects are treated as components for building learning environments, it is appropriate to transfer the lessons learnt in object-oriented software development to learning objects design (Boyle 2003; Douglas 2001). Boyle (2003) adapted the following two principles of object-oriented development to learning objects: (1) cohesion – each object aims at one learning objective or one goal; (2) minimised coupling – each learning object should have minimal binding with other learning objects so that unnecessary dependencies are avoided. This emphasises the idea of multiple smaller units that can be built into larger learning objects.

Thus we propose a model of learning objects comprised of building blocks. Building blocks can be defined as reusable digital multimedia resources that are easy to combine into learning objects. Although each building block on its own may not be sufficient for learning, their combination should result in a valuable learning object. The concept of building blocks is derived from the work of Polsani, who regarded learning objects as "the arrangement of elements" where "an element could be text, image, video, animation, glossary, assessment, or multimedia. Preferably a LO should be a combination of multiple elements" (Polsani 2003, online, section 1.2).

Our research question asks: "what are the most appropriate principles for designing building blocks for learning objects?" Our objective is to create a set of newly synthesised principles for designing building blocks for learning objects based on the previous literature and established methodologies (e.g., Boyle 2003) We then augment the synthesised set of principles with additional principles derived from our own teaching experience. Following Boyles's approach we then operationalise the principles to test in the classroom setting.

The principles we have built from the literature are as follows:

1. Each building block should be an independent entity.
   This principle ensures that each building block is flexible and reusable. This supports the need for learning objects to be cohesive as recommended by Boyle (2003).
2. Minimised coupling ensures minimal binding with other building blocks.
   This principle also creates greater flexibility because reduced coupling ensures that change to one building block has a low impact on other building blocks; that is, the use of each individual building block has a low level of dependence on other blocks (Boyle 2003; Larman 1998).
3. Being attachable ensures that multiple building blocks can be combined together to create complex learning objects.
   This principle is fundamental to our definition of building blocks and is based on principles for creating complex multimedia objects (Cybulski & Linden 2000). Also this principle supports construction of composite learning objects (defined by Liber (2005) as generativity).
4. Building blocks should be designed to allow reuse of the same building block for construction of different learning objects in various contexts.
   This principle is derived from object-oriented design where reuse is a core concept (Booch 1994). Reuse and adaptability to different learning contexts is strongly emphasised by learning object researchers (Cameron & Bennett 2010) and therefore can be considered an important feature of building blocks.
5. Each building block could potentially be a subject of generalisation.

This principle is also derived from object-oriented design concepts which promote generalisation and reuse (Booch 1994). By applying this principle designers can recycle building blocks across multiple learning objects. For example, a template may be developed which could be used to create multiple instances of building blocks.

Our goal was to create a set of customisable learning objects suitable for a blended learning environment, an environment where face-to-face instruction is complemented by e-learning (Hadjerrouit 2008). These principles support this goal. A further principle, derived from our empirical work, is presented in the Discussion section.

In the next section we describe how we applied our principles for aggregating multimedia building blocks into learning objects in the programming context.

4 RESEARCH APPROACH

The research project involved the following 6 stages. These were designed to support the research objective of using the principles proposed above to build multi-media building blocks and to construct effective learning objects:

1. Identifying a suitable topic for the creation of learning objects.
2. Creating animated learning objects on this topic, based on the principles listed above (e.g. reusability, minimised coupling). Using building blocks for populating a variety of learning objects.
3. Demonstrating these objects to a class of 78 students (1 lecture and 4 tutorial groups). These students were enrolled in the subject “Introduction to Programming Concepts”.
4. Feedback from students. Collecting formal (via a questionnaire – see Appendix 1) and informal feedback from the students.
5. Observing active learning via students’ creation of their own learning objects.
6. Feedback from staff. Surveying off-shore staff on their perception and use of the learning objects.

The topic chosen as context for the creation of the learning objects was passing parameters between program modules and their representation in RAM. The research literature suggests that students find topics related to RAM handling during program execution particularly difficult (Milne & Rowe 2004). One of the challenges is teaching dynamic concepts using static materials (Gomes & Mendes 2007). Teaching staff use whiteboards, static presentations and printed materials, such as notes and textbooks, to explain concepts such as program behaviour, dynamic memory allocation or change of variables’ values during program execution. Students learning these concepts often find it hard to imagine, for example, how each source code instruction is processed by the computer and what is happening inside RAM as program statements are executed. There is a strong belief among computer science educators that visualisations help in understanding programming concepts (Naps et al. 2003). Research has compared understanding of programming concepts by students with access to a visualisation environment and students without such access (Smith & Webb 2000). Their findings provide some preliminary support for what many educators already believe from their experience that visualisation tools are of great help to learners. Further research into visualisation in support of teaching programming concepts investigated integration of visualisation and cognitive conflict strategy to improve understanding of programming concepts (Ma et al. 2011). This work produced some promising results.

This concurred with the experience of the authors of this paper and supported the idea of providing visualisations as learning objects. Using the topic “Passing parameter to procedures and functions” we created a set of digital learning objects. The learning objects were specifically designed to teach what happens in RAM when the main program calls a procedure or a function and passes parameters to that procedure or function.

Like many other academics before us our approach had previously been to draw RAM on a whiteboard as a collection of cells and to use different coloured markers to show changes during program execution. However, students trying to listen and make notes would lose track of which instruction execution was being explained. This approach was also of little help for students who missed the class or who did not remember the explanation and needed to view it again.

To solve the problem of using static whiteboard drawings to demonstrate dynamic changes in program execution, examples illustrating states of RAM were developed and embedded into lectures as animated PowerPoint presentations. A separate slide was devoted to each statement in the code (or even a specific part of the line in the code which was emphasised in the explanation). That line of code was enlarged to stand out. At the same time a narrated animation showing what happens when this bit of code executes, provided a verbal explanation of what was visible. For example, the slide captured in Figure 1 demonstrates the creation of value parameter Y (i.e. a copy of the actual parameter). In the figure, RAM locations used by the procedure Button1_Click() are depicted in red and RAM locations used by the procedure calculateSum() are in blue. The intention of colour coding is to help students better understand memory allocation and use during program execution. The figure depicts the part of the animation which demonstrates that a value parameter Y (in blue) is a copy of the actual parameter Y (in red), meaning that at run time the value of 40 from the red box will be copied to the blue box. The colour change effect is used to show that red Y with the value of 40 is controlled by the procedure Button1_Click() whereas the blue box Y belongs to the procedure calculateSum(). When 40 moves from the red box to the blue box it gradually changes its colour from red to blue.

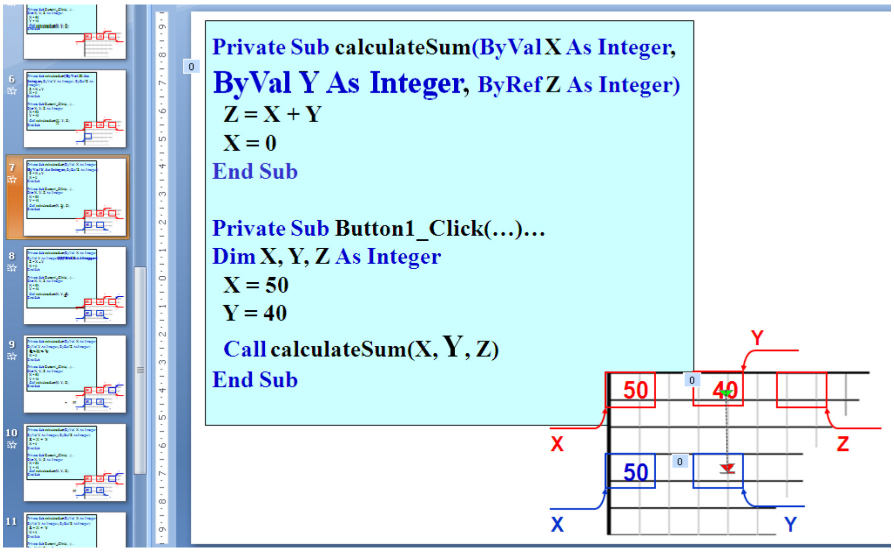

Figure 1. *A screenshot of one of the PowerPoint animations: the slide shows the creation of the value parameter Y in RAM*

As part of our development process in Stage 2, two teaching staff sought initial feedback from the student group on the use of animations. The stages 2-4 were iterative (feedback / development / feedback). Feedback was initially sought through informal discussions in tutorials after students were exposed to multiple examples of small animated program excerpts illustrating a programming concept. The initial presentation was decomposed into building blocks from which multiple similar presentations showing simple programs with small modifications were constructed (for example, by changing values and/or variable names).

To elicit the informal feedback we asked students the general question of whether the animations helped their understanding of concepts. Discussion took place across 4 tutorial groups and was audio recorded and transcribed. The transcripts were coded using NVivo. Open and axial coding cycles were used to induce propositional statements from which the three themes detailed in the Results section emerged (Neuman 2003).

Earlier in this article we proposed five principles for building blocks based on previous literature. We applied these principles while creating our building blocks. The building blocks used in our study were in various multimedia formats, e.g. text (for slide narration) and corresponding mp3 voice recordings, images (a set of cells representing RAM) and individual PowerPoint slides. Following Principle 1, each block was an independent entity that could be modified and reused as well as attached to other building blocks (e.g. both narration text and mp3 files could be attached to PowerPoint slides). The PowerPoint environment was chosen as ideal for aggregating building blocks of various multimedia formats into a complex learning object. It also supports reuse and easy modification of animated slides. Use of Web 2.0 applications provided opportunities in format conversion (e.g. spokentext.net was used to convert text to audio, screen capturing was used to create video from PowerPoint animations).

Over time the staff had developed a library of visual presentations as well as building blocks. However, while this approach helped students attending lectures it did not solve the problem of concepts revision or help students who missed the class. We needed to develop materials that could be stored and accessed on demand. We decided to develop videos containing animated explanations of concepts with narration, since we could take advantage of easily available Web 2.0 technologies. Initially videos were recorded using screen capturing packages with voice recording (for example, screenr.com, Camtasia, BB Flashback). These videos were produced as Flash animations for viewing over the Web as well as .avi and .exe files that students could run on their computers without depending on the Internet and website availability or download limit.

In the process of developing the videos the principles of “minimised coupling” and “attachability” (Principles 2 and 3) listed earlier were applied. That is, voice narration was recorded for slides as individual mp3 files and attached to PowerPoint animations. Such an approach provided for easy maintenance, e.g. if it was decided that a slide could be explained in a better way, only a small mp3 needed re-recording. Also the same narration files were applicable in several different animations so these building blocks were reused across learning objects. For example, Figure 2 shows two sample exercises that were used to gradually build students understanding in parameter passing. In both examples first parameter A is passed by value, therefore the slides showing RAM states and narration for those slides will be the same for both presentations. Thus once built for the first learning object these building blocks will be reusable for creating the second learning object.

Example 1. Passing parameters by value in an abstract context	**Example 2. Passing parameters by value and by reference in an abstract context**

Private Sub makeChanges(ByVal A As Integer, ByVal B As Integer)
  B = 4
  A = 5
end Sub
 	
Private Sub Button1_Click()…
Dim X, Y As Integer
  X = 10
  Y = 20
Call makeChanges(Y, X)
End Sub
	Private Sub makeChanges(ByVal A As Integer, ByRef B As Integer)
	  B = 4
	  A = 5
	end Sub
	
	Private Sub Button1_Click()…
	Dim X, Y As Integer
	  X = 10
	  Y = 20
	Call makeChanges(Y, X)
	End Sub

Figure 2. Examples of exercises on parameter passing

Part of our approach was to accommodate the multicultural nature of the Australian educational environment. Many academics are migrants speaking English with various accents, thus accents sometimes interfere with student understanding of teaching instructions. Sometimes the difficulty is not in understanding the material as in understanding what the instructor is saying. Since narrations in this project were recorded in mp3 format, we explored text to speech software utilisation in replacement of self-recording. (Conversion facilities are available as standalone software such as Natural Reader or through the Web, for example, http://vozme.com or http://spokentext.net). In this way the principle of reusability (Principle 4) was applied as well as other principles, such as minimal coupling and attachability (Principles 2 and 3).

Previous research has shown that passively watching videos is of lower educational value than active learning engagement (Naps et al. 2003) even though video materials are a valuable supplement to lectures and revision sessions. In active learning approaches students were involved in the creation of learning objects which were later added to learning object systems (Bannan-Ritland et al. 2002; Dale & Povey 2011). Consequently, in the study students were engaged in constructing their own learning objects (in this case animations) as recommended by Hundhausen and Douglas (2000) as well as by Parrish (2004). This was done initially by offering an exercise in class and making students contribute to the construction of the animation via desktop-sharing (the tool from the join.me website was used to give all students in class access to the same desktop from their workstations or laptops). Then students were asked to work in groups of 2-3 people, each group working on their exercise using some of the existing building blocks to make the development experience easier. This approach gradually built students' confidence in dealing with questions they considered difficult. (Students were not asked to record narrations, just develop PowerPoint animations, however good quality solutions were added as building blocks to our multimedia library). This activity also provided some benefits as part of group collaboration where more capable students were learning during the process of development while explaining their actions to other group members. Regrettably not every group succeeded in this type of exercises (across 4 tutorials we had only 9 groups that successfully developed animated solutions to the exercises).

Building on this idea, students were offered more exercises to develop animations as revision for tests. Then students were asked to produce their own code examples and develop animations in PowerPoint illustrating changes in RAM as their code executes. Students had access to existing building blocks. Some of them continued working in teams and used approaches they learnt in class, such as using join.me to collaborate while working from home.

Student feedback was also sought formally through a questionnaire (see Appendix 1) distributed via the university learning management system. The questionnaire asked them questions about their experience in learning through the animations and through the traditional method of a lecturer developing a programming example on the whiteboard.

Finally, three off-shore staff members were given access to learning objects and the building blocks from which those objects were constructed. Later they were asked via email (see Appendix 2) to send feedback on their perception of learning objects, their suitability for teaching international students coming from non-English backgrounds and whether they applied any customisation to the provided learning objects.

5 RESULTS

The six research stages described above generated four (4) categories of results: observations during the development process, informal feedback from students, formal feedback via the questionnaire and feedback via email from offshore staff.

During the development process we discovered several cases where building blocks had to be converted from one format to another. First it was necessary to convert concept explanations from text to audio format to associate bits of audio with specific PowerPoint slides. During the development of narrations we realised that storing them as building blocks made them more reusable and customisable. Having these building blocks as text provided easier ways of translating them into other languages or generating audio with different accents. The videos were converted afterwards to Flash format for student access over the Internet. Then they were converted to executable format to make them available in Internet-free environments. Consequently the students involved in this research were presented with multiple options for accessing instructional videos. Additionally off-shore staff had the option of presenting videos without recorded narration (i.e. providing live explanations) or with narrations in English or in their native language.

Students and staff who participated in the development process were unaware of the concept of building blocks and learning objects. Students perceived the exercises as creating animations. However, the use of building blocks made the whole approach to speedy creation of animated learning objects feasible. Our results show that through the use of building blocks our students were able to create their own videos and the off-shore staff were able to replace narrations with the ones suitable for their students.

Informal feedback (stage 4) was coded into three themes. Under each theme we provide sample quotes (quoted verbatim).

- The developed learning objects assisted in both the understanding of concepts and problem-solving:
    - Quote 1: "I can see changes in memory and it help me understand this difficult topic. Now I understand the difference between value and reference parameters."
    - Quote 2: "Animated explanations are easier to understand than when you draw diagrams on the whiteboard."

- The developed learning objects assisted in concepts revision:
    - Quote 3: "Please create more such animated exercises for the exam preparation."
    - Quote 4: "These animations help solve problems when preparing for the test because you use them as a solution for the example and you solve a similar exercise."

- Students who opted to create their own learning objects appreciated a non-traditional learning experience:
    - Quote 5: "I did not expect programming to be fun but developing these animations is more interesting than writing solutions on paper."
    - Quote 6: "I feel that I understand the concepts better after I created my own animations. It feels good to know that you will use my animations to teach other students."

Formal feedback via the questionnaire also showed that the majority of students preferred the use of animations in their learning. Fifty six (56) students responded to the questionnaire. Student response overall indicated that animations were a useful tool for conceptual learning. These findings are summarised in Table 1and Table 2 below.

Selected *a.* *Diagrams on the whiteboard*	Selected *b.* *PowerPoint animations*	Selected *both a and b*
3	46	7

Table 1. Questionnaire data summary - question 1 results.
Question 1. Which of the two methods was more helpful in understanding the concepts of parameter passing?

Question	*Yes*	*No*
2. Would PowerPoint animations with recorded narration be sufficient for you to understand the concepts without attending the class?	52	4
3. Would you use PowerPoint animations for revision in your own time in addition to class sessions?	49	7

Table 2. Questionnaire data summary - questions 2 and 3 results

While it is encouraging that the offshore staff reported informally (stage 6) that final subject marks of this student group were slightly higher than previous groups who did not have access to animations, this does not provide a true evaluation of the learning objects described here as students' performance is affected by multiple variables.

The offshore teaching staff involved in the study reported some immediately assessable benefits beyond improved results:

Quote 7: "I used animations in lectures to explain concepts of parameter. I would play the video, then I would pause it and explain the slide again. Then run the next part of the video explanation. If necessary I would rewind the video to explain the difficult part again and again – really helped in my teaching".

Staff found it easy to adapt learning objects to the needs of their students by replacing a building block with a more suitable one (mainly by rewording explanations and attaching updated mp3 recordings to slides since their students had difficulty understanding accent in the original recordings; therefore they provided recordings in 2 languages – English and native). They appreciated access to customisable learning objects without involving professional educational designers and without the added overhead of learning complex software packages. The teaching staff who had previously used traditional teaching methods reported a real enthusiasm from students and genuine energy in the classroom.

6 DISCUSSION

We started our empirical work using five principles for designing learning objects from building blocks that we derived from the literature. Our empirical work suggested a further important principle and significant new contribution for the development of building blocks and learning objects:

Principle 6: The way building blocks are represented should allow conversion between formats.

This principle emerged from our results where we discovered the benefit of having concept explanations in different formats, such as text script and audio recording. Similarly the resulting learning videos were provided to students in different formats (avi, exe and as Flash embedded in web pages). Providing flexibility in formats caters for the needs of developers as well as end-users.

Our work provides some initial support for the idea that by following propositions for OOID (Boyle 2003; Douglas 2001; Parrish 2004) and applying them not only to learning objects but also to building blocks we can avoid issues such as the high cost of development and the risk of "sacrificing the semantic environment for the sake of creating context free learning objects" that Parrish warned against (Parrish 2004, p.62). This was evidenced in our results by staff comments about their ability to easily replace and reuse building blocks and develop materials without needing to learn or buy complex software.

Our work supports Parrish's proposition that learning objects as well as building blocks should be considered within a learning context. Although such an approach may limit the applicability of building blocks outside the context of the particular learning topic, we have seen that there is still enough flexibility for reuse and modification by other users. For example, in explaining the concept of variables and memory allocation the same mp3 recording could be reused for teaching different programming languages and an animated slide may need only a slight modification by switching from the syntax of one programming language to another, where, for example, a parent program, PowerPoint, facilitates an easy change. This is evidenced in the way staff found the learning objects easy to adapt in the same teaching context by replacing a building block with a more suitable one (as described in results section). Thus we demonstrate that Parrish's suggestion – "create techniques that allow instructional designers to interrupt and annotate learning objects at many articulation points" (Parrish 2004, p.63) can be easily applied. However using our approach such modifications are even simpler to implement since the learning object is composed of the building blocks.

We used learning objects to support active learning strategies by engaging students in the construction of their own learning objects from modifiable building blocks. This trial demonstrated dual benefits: students attested to an increased interest in learning programming concepts (quotes 1, 2 and 6) and we had more learning objects to use in our teaching. The same building blocks could be suitable for other academics teaching RAM-related topics using the same programming language or different ones (concepts are still the same, only the syntax changes). Also the offshore staff we sampled reported that they took full advantage of learning objects as well as building blocks. Due to the inherent features of video learning objects during class sessions they could add their own on-the-fly explanations, rewind and repeat explanations using different words (quote 7). This option was of substantial help to students with English as a non-native language. However, they also easily customised the learning objects by replacing building blocks with more suitable ones for their students.

We have used this approach outside of the programming context and suggest it has broad application in many instructional contexts. The principles tested here were used to develop learning objects from building blocks in the subject Systems Analysis focusing on requirements gathering. One of the lecturers developed scenarios of interviews between the systems analyst and a client. The lecturer recorded her own voice as a customer and used text-to-speech software for the systems analyst. Each part was stored as a separate mp3 file (an individual building block). Originally the scenario was played for students as an audio scene only and then systems design implications of the case were discussed. In a later semester a Web 2 application powtoon.com was used to show two windows simultaneously. In one window a systems analyst was calling, in another – the client representative was taking the call. Audio building blocks were reused in production of this video. Potentially this video can be used by offshore providers where they could replace the audio with recordings in the students' native language. Additionally, the building blocks used to model the communications with the customer provide a template for a relatively generic scenario; therefore the video can be reused with the audio describing a different case.

As stated earlier, Parrish (2004) recommended that learning objects be more than "simply libraries" for students to access out of class (p.62). Students have always had difficulty revising missed concepts and have not been well assisted by stored PowerPoint slides of lectures (Susskind 2008). Our videos containing animated explanations of concepts provided engaging learning objects which enrich the learning experience beyond just a stored PowerPoint of the lecture (see quote 4). These objects were also easy to use and share without needing to be online.

Our approach also addresses Parrish's concern about development costs because it provides for use of various packages by academics themselves rather than hiring professional designers. We also believe that the quality of learning objects is higher when designed by the people who will use them, rather than by generalist educational designers. The software cost is minimal since many universities have site licenses for Microsoft Office (for example, PowerPoint) and some Adobe software. In addition there are multiple easy to use Web 2.0 applications available on the Internet either as freeware or shareware.

As a limitation of this study we point out that no testing took place in pure e-learning / distance learning environments, however the approach excels when applied in blended learning environments to enrich and supplement face-to-face teaching. As part of informal feedback we learnt that students used the latest technology to get the most benefit from access to learning objects. For example, they watched animations on their mobile devices as preparation for tests while travelling on public transport; one student mentioned that he used his laptop on the go for animations development.

7 BENEFITS OF BUILDING BLOCKS FOR LEARNING OBJECTS

There is a view that educators are not keen on reusing teaching materials developed by others because of differences in teaching philosophies (Westfall 2000). Every instructor has their own way of presenting material which is adjusted as an educator reflects on what he has taught and how students have responded to it in completing assessment. However, some of this reluctance comes from the lack of availability of useful shareable objects which we believe can be at least partially overcome by the approaches we have outlined.

Having access to the building blocks of multimedia materials that we have described makes it easy to construct the most applicable learning object to assist in explaining concepts and to easily replace any block with an improved or modified version as it becomes available. Thus materials can be updated and tailored for individual classes and ability levels.

The proposed approach does not rely on a special environment or expensive software packages and so it is suitable for any enthusiastic academic. Furthermore, developing the described materials does not create a significant additional workload or learning curve for instructors. There is flexibility in choosing software packages with which a developer is already familiar and comfortable.

Students can also be involved in learning materials development and therefore engage in additional opportunities for their own learning thus implementing the well-known “learning by doing” approach (Anzai & A.Simon 1979). As a result of students activities teaching staff may get a larger set of learning objects to use in their teaching.

The ability to quickly construct learning objects from multimedia building blocks also supports an adaptive learning approach (Magoulas et al. 2003). Fast learners could be presented with 3-4 learning objects as examples and exercises to learn a concept whereas slower learners can be offered a more gradual approach with additional learning objects being created from multimedia building blocks within short periods of time to meet students’ needs.

8 CONCLUSIONS

The contribution that we make in this paper is to extend and enrich previous studies of learning objects and object-oriented instructional design by proposing a set of principles for creating and aggregating multimedia building blocks into learning objects. In these principles, we extend earlier ideas about learning objects and show how they can be applied at the building blocks level. We derive these principles while developing learning objects in the context of programming concepts subjects as well as show how it can also be generalised successfully to other educational contexts including other computer science subjects. The techniques discussed provide ways for instructors to develop customisable building blocks and assemble them into learning objects, adapted to meet the individual needs of students. These approaches were met with enthusiasm by both students and educators.

As well as addressing some of the concerns raised by Parrish (2004) over cost and adaptability, our approach also demonstrates the usefulness and applicability of his propositions for OOID. As a result of the development process it became evident that while Boyle (2003) proposed learning objects as useful units to work with, smaller building blocks were in fact more effective in the development of multimedia teaching materials. In sharing our experience in engaging students both in learning activities and active development of learning objects we found that while students find fully built learning objects helpful for their learning, such objects are not flexible and not always reusable in their complete form. Consequently our principles for development that start with decomposed individual objects provide improved opportunities for effective development of learning objects using a library of building blocks.

APPENDIX 1 – THE QUESTIONNAIRE DISTRIBUTED TO STUDENTS

The following questionnaire is confidential, anonymous and participation is voluntary.

To explain the differences between value and reference parameters you were shown examples similar to the one below:

```
Private Sub calculateSum(ByVal X As Integer,_ ByVal Y As Integer, ByRef Z As Integer)
  Z = X + Y
  X = 0
end sub

Private Sub Button1_Click()…
Dim X, Y, Z As integer
  X = 50
  Y = 40
  Call calculateSum(X, Y, Z)
end sub
```

Solutions were explained in two ways: by drawing diagrams on a whiteboard and by using PowerPoint animations with the lecturer narration. Please give us your feedback on the suitability of each of the methods:

1. Which of the two methods was more helpful in understanding the concepts of parameter passing:

    a. diagrams on the whiteboard   b. PowerPoint animations

2. Would PowerPoint animations with recorded narration be sufficient for you to understand the concepts without attending the class?   Yes / No

3. Would you use PowerPoint animations for private revision in addition to class sessions?   Yes / No

4. If you have any suggestions regarding animations, please use the space below to share your thoughts with us.

APPENDIX 2 – QUESTIONS SENT TO OFFSHORE STAFF

1. Did you use animations for presenting material in lectures?
2. How did students respond to the use of animations?
3. Did you use the provided building blocks (i.e. PowerPoint version and mp3 recordings) to make any changes to the animations?
4. Did access to building blocks assist or encourage you to adapt animations to your students' needs?

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