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# The Role of Scaffolding in the Design of Multimedia Learning Objects

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Scaffolding mechanisms to support learning, such as feedback on interactions, play a critical role in determining the pedagogical design of multimedia learning objects. *Procedural*, *conceptual*, *strategic* and *meta-cognitive* scaffolding each make a distinct impact on learning design and so can potentially either support or conflict with the intended learning design principles. This paper reports on the initial development and application of a scaffolding analysis procedure and discusses its potential to mediate the quality of designs.

## Context of the study

The Learning Federation (TLF), a government funded initiative, is creating large quantities of high-quality online curriculum materials, known as 'learning objects' for teachers and students in Australian and New Zealand schools. The TLF (2005) definition of a learning object states that it is "one or more files designed to be used as a standalone learning experience – a 'chunk' of material (which might consist of audio, graphic, text, animation or some relevant mix of components) that will make sense to the learner by itself". Recent research has shown that the learning objects created by TLF effectively motivate and engage students in learning activity, and have the potential to enhance student attainment (Freebody, Muspratt & McCrae, 2007).

The development of these teaching and learning resources have demanding pedagogical and instructional design expectations, further complicated by restrictions embodied in technical specifications. These restrictions exist to ensure learning objects technically follow internationally accepted standards that are consistent and maximise viability, integrity and portability of content (The Learning Federation, 2007). However, as pointed out by Haughey & Muirhead (2005), tensions exist between such limitations and pedagogical ideals, "Instructional designers and educators have had to consider the competing characteristics of reusability versus localisation or specificity, and of instructivist and constructivist learning theories, as well as multimedia affordances" (p.1).

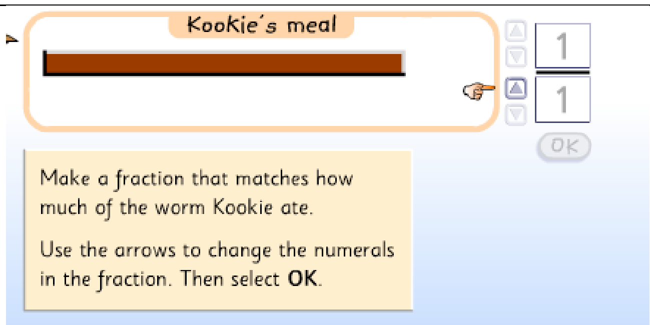
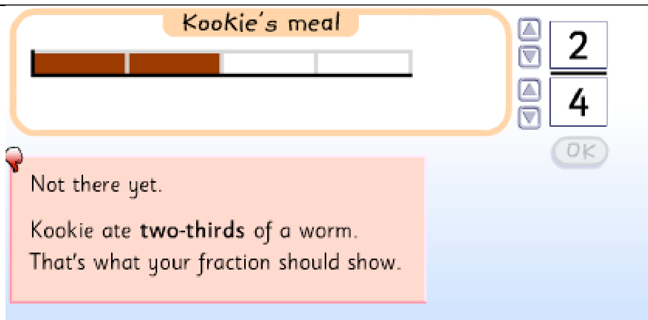
The TLF advocates an approach to learning design that is "underpinned by constructivism, problem-based learning, inquiry (investigative) learning, situated authentic learning contexts and provision of constructive purposeful feedback to students about their learning" (Atkins & Jones, 2004, p.4). The constructivist view of learning holds that the learner is an active participant in the learning process, with each learner interpreting experiences and connecting concepts and understandings in his/her unique way. The Vygotskian notion of constructivism contains the key element of 'scaffolding', which can be defined as appropriate (in terms of the 'zone of proximal development' or challenge level) and timely learning support provided by a 'teacher'. The teacher role can be filled by an adult or peer, or in the case of a learning object, the provision of some form of guidance, additional information or feedback in response to the learner's interaction. The TLF design guidelines place an emphasis on the use of feedback as a key mechanism for scaffolding learning, and as a result, feedback plays a major role in shaping the actual learning design for each single learning object.

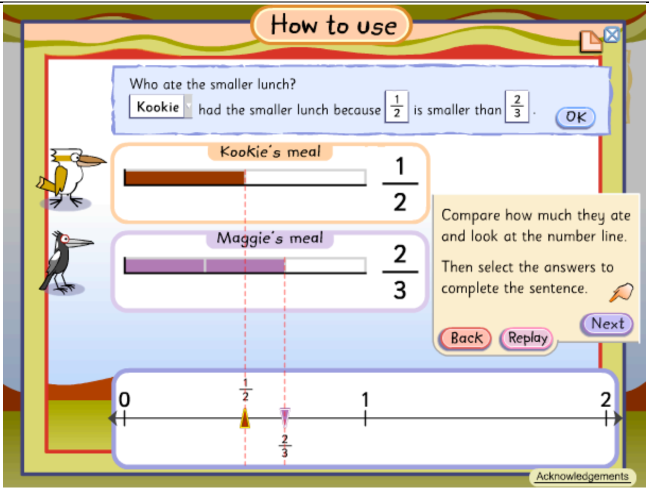
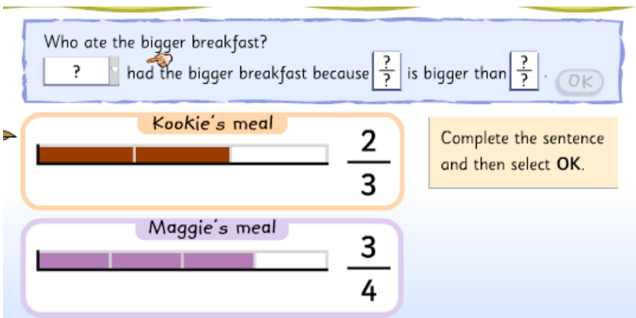
## Types of scaffolding for learning

In their paper defining digital resource-based learning environments, Hill and Hannifin (2001) describe four types of scaffolding that support learning: *procedural, conceptual, strategic* and *meta-cognitive*. This typology of scaffolding was developed in the context of 'open learning environments' (see for example, Hannifin, Land & Oliver, 1999; Hill, 1999), but has also been applied, to some extent, to the self-contained learning environments of single learning objects. For example, Orrill (2001) uses three of these scaffolding types, *conceptual, strategic* and *meta-cognitive* to help describe the role of component learning objects in an Inquiry-based online learning environment. Haughey and Muirhead (2005) also applied these three scaffold types in their review of a sample of 35 of TLF's learning objects, across several curriculum areas, concluding that each type was present, though *meta-cognitive* scaffolding was under-utilised. (No explanation was provided by the researchers for the omission of *procedural* scaffolding in these two studies).

The dominant purpose of scaffolding is to support learning by reducing cognitive load and allowing the learner to focus on constructing knowledge and higher-order demands such as complex processes, hierarchical conceptual relationships or critical thinking. These higher-order demands may lead to deeper understanding. Table 1 presents the characteristics of each type of scaffolding, which have been primarily derived from Hill and Hannifin (2001), but adapted in relation to their application to individual learning objects. A trial application of the descriptions to a TLF learning object by the researchers provided tentative evidence of their relevance.

Table 1: Types of scaffolding

| **Scaffolding Type** | **Description** | **Example from TLF Learning Object** |
|---|---|---|
| Procedural | Assists with how to use the resource - so focuses on using specific functions, procedures or navigations. |  Instructions and 'pointing hands' guide the task steps and direct attention to the interaction needed. |
| Conceptual | Assists in focusing thinking, prioritising information, making connections between concepts or in simplifying complex concepts Supply of a conceptual model or different representations of a concept. |  Feedback for an incorrect fraction representation focuses attention on the key concept – which relates to connecting the symbolic and diagramatic representations of the fraction. |

| | | |
|---|---|---|
| Strategic | Assists by directly or indirectly suggesting approaches, strategies or pathways to achieving learning |   The instructions include direct advice on strategy for achieving the learning goal by comparing the representations (Also connection of conceptual representations) |
| Meta-cognitive | Assists the learner to reflect on what they have learnt (self-assess), or reflect on how they are learning (awareness of processes). It may be in the form of a simple prompt to think about the goal or problem; or it may be more sophisticated guidance for organising or assessing knowledge. |   Completion of the solution statement prompts reflection on what has been discovered through the process of comparing the fractions using visual models. |

## The study

The purpose of this study was to investigate the potential of an analysis of scaffolding types to evaluate existing and inform future, pedagogical design of TLF mathematics learning objects. The pair of researchers began with collaborative interpretation and refinement of the scaffolding descriptors extracted from the literature (See Table 1) and development of analysis procedures through application of the descriptions to one learning object. As participants in The Learning Federation project, the researchers had access to the full bank of learning objects.

TLF usually produces sets of three to nine closely related learning objects, called series. These series are grouped into eight content areas. One learning object was chosen from each content area, each from a different series and together covering the target-age range of 5 to 15 years. An additional learning object was selected to represent the type of learning object design referred to as an open-ended 'tool' (which allows for custom input of content), giving a total of nine learning objects for the exploratory analysis (See Table 2), which covered about 12% of the 71 series of learning objects (though only 2% of the total individual learning objects) that had been published by TLF up until March 2008.

The researchers independently analysed half of the learning objects, then cross-checked each other's consistency of judgement.

Table 2: List of learning objects in analysis sample

| Content Area | Learning Object Title & ID Code | Age Level |
|---|---|---|
| Number: exploring number | Number trains: numbers 1–10 (L2318) | 5 years |
| Measurement | Finding the area of rectangles (L384) | 5-7 years |
| Number: addition, subtraction, division and multiplication | Divide it up: puppies * (L2808) | 6-10 years |
| Algebra | Balance the blobs: find the rule 1 * (L5979) | 8-9 years |
| Number: common fractions, decimal fractions, percentages | Fraction fiddle: comparing unit fractions (L2802) | 8-12 years |
| Space | Shape maker: replicator (L1059) | 9-12 years |
| Chance and data: chance focus | Spinners: advanced builder (tool) (L2377)<br>Dice duels: airport addition (L2323) | 8-12 years<br>12-15 years |
| Chance and data: data focus | Graph investigator: hand preference (L5906) | 12-15 years |

*These learning objects are accessible to the public at http://www.thelearningfederation.edu.au/for_teachers/sample_learning_materials/tm_-_maths.html

Each learning object was examined screen-by-screen and the scaffolding categorised as *procedural*, *conceptual*, *strategic* or *meta-cognitive*. A statement justifying the categorisation was recorded together with a screen grab to illustrate the occurrence. Where a screen contained several components that served different purposes, for example both *procedural* and *conceptual*, then both categories were allocated. If the same features were later repeated in very similar circumstances, then it was not recorded a second time. Similarly, minor scaffolding features, such as arrows or pulsating buttons, were only noted if significant to progress through the tasks or for realising learning opportunities, and were not recorded again if repeated on later screens. This analysis procedure was followed to avoid misleading dominance of trivial or repetitive scaffolding when frequency of scaffolding occurrences is considered.

## Results and discussion

The exploratory nature of this study, and the relatively small sample of learning objects used, require that any conclusions drawn from the analysis data be restricted to informing the design of further research rather than generally evaluating the use of scaffolding in TLF learning objects.

### *Scaffolding type frequency*

The analysis revealed that all four types of scaffolding are present in TLF learning objects, though in differing degrees (Table 3). Of the 118 occurrences of scaffolding noted, the majority (72.8%) were *procedural* and *conceptual*. All but one learning object contained at least one instance of *strategic* scaffolding, but four of the learning objects contained no *meta-cognitive* scaffolding. Though the information gained from the frequency data is quite superficial, it is useful in that it suggests a trend that is consistent with the findings of Haughey and Muirhead (2005), which indicated a paucity of *meta-cognitive* scaffolding. In order to judge the significance of the absence of deliberate placement of scaffolding to stimulate *meta-cognitive* activity, it would be necessary to examine the stated intended learning outcomes for each learning object. For example, if the learning goal were to understand how to find the area of a rectangle, then the presence of *conceptual* and *strategic* scaffolding would be expected, but *meta-cognitive* scaffolding may not be necessary. However, if the learning goal were to select and develop effective problem solving processes, the absence of *strategic* and/or *meta-cognitive* scaffolding would be of concern.

Table 3: Frequency of occurrences of scaffolding types (n=125)

| Learning Object Title | Procedural | Conceptual | Strategic | Meta-cognitive |
|---|---|---|---|---|
| Number trains: numbers 1–10 | 3 | 2 | 0 | 0 |
| Finding the area of rectangles | 4 | 5 | 4 | 0 |
| Divide it up: puppies | 5 | 3 | 1 | 2 |
| Balance the blobs: find the rule 1 | 4 | 5 | 3 | 2 |
| Fraction fiddle: comparing unit fractions | 4 | 5 | 1 | 2 |
| Shape maker: replicator | 7 | 6 | 1 | 3 |
| Spinners: advanced builder (tool) | 2 | 5 | 3 | 2 |
| Dice duels: airport addition | 11 | 6 | 6 | 0 |
| Graph investigator: hand preference | 7 | 7 | 4 | 0 |
| Totals | 47 | 44 | 23 | 11 |
| Percentage | 37.6% | 35.2% | 18.4% | 8.8% |

It is interesting to note that no *meta-cognitive* scaffolding was recorded for the youngest and oldest age levels, though the small sample prevents generalisations being made.

***Scaffolding delivery***

The scaffolding is delivered to the learner in four main ways:

- Linear mode, which is presented as the learner moves through the screens of the learning object and is therefore obligatory for the learner.
- Optional pathways, such as 'How to Use' sections or additional information.
- Feedback triggered by the learner's correct or incorrect responses.
- Closing actions, such as referring back to the original goal, or requesting a print-out of a new task.

About half (51.2%) of the scaffolding was built into the primary interface of the learning object, which means that the learner cannot avoid it (Table 4), even if it is not needed. Most of the remaining scaffolding (44.8) is delivered on a 'needs' basis, through either optional pathways (mostly 'How to Use') or as feedback on responses. Interestingly, the 'How to Use' sections, present in six of the nine learning objects, accounted for 16.8% of the scaffolding and covered all four types. Of the small amount of *meta-cognitive* scaffolding, more than half of it is only encountered if the learner chooses assistance, receives it in feedback, or chooses to print out a take-away record of the activity or further task.

Table 4: Percentage of instances of scaffolding in each delivery mode (n=125)

| Delivery mode | Procedural | Conceptual | Strategic | Meta-cognitive | Total |
|---|---|---|---|---|---|
| Linear - Unavoidable | 27.2 | 15.2 | 5.6 | 3.2 | 51.2 |
| Optional pathways | 4.0 | 8.0 | 4.0 | 0.8 | 16.8 |
| Feedback on learner response | 5.6 | 12 | 8.8 | 1.6 | 28.0 |
| Closing act or print out | 0.8 | 0 | 0 | 3.2 | 4.0 |

***Types of learning object design***

One aspect that was not well explored in the small sample of learning objects was the relationship between differences in the overall learning design and the use of scaffolding. Most of the learning objects in our sample were of linear design, offering little or no choice of pathways through to the learning goals. Only one open-ended tool, which requires the learner to determine their own learning goals, was included in the sample. No game formats were included. Analysis of a greater range of design types would allow comparisons in the quantity and types of scaffolding present in these differing designs.

**Hierarchies of learning and scaffolding**

When viewed in terms of established hierarchies of thinking such as Bloom's taxonomy (Bloom & Krathwohl, 1956), the types of scaffolding are arguably also hierarchical, with *procedural* being low level, *conceptual* and *strategic* mid-level due to the role of understanding and application of understanding, and *meta-cognitive* being high level because of its reflective and evaluative nature.

In relation to the learner, another hierarchy exists in terms of the observability of the responses to the scaffolding. Response to *procedural* scaffolding is physically observable through the learner's direct interaction with the interface, such as clicking on the appropriate region. Learning reaction to *conceptual* or *strategic* scaffolding may be observable to some extent depending on the specific circumstances. For example, an observable reaction would be a correct response after receiving *conceptual* feedback on an incorrect response. However, on another occasions, the reaction might be internalised thought-processes that lead to conceptual understanding that cannot be immediately demonstrated through a specific physical interaction. *Meta-cognitive* scaffolding is intended to support higher-order thought processes and so tends to engage the learner with ideas or abstractions rather than with physical models in the learning object. Therefore, the reaction is internalised and may not be demonstrated through observable interaction with the interface. If observable evidence of learning is a design requirement, then *meta-cognitive* activity may have been avoided in learning object design.

There is some evidence to suggest that the learners themselves are aware of the value of particular design elements, including scaffolding, but question the appropriateness of the cognitive demand inherent in the learning objects. A study of the use of TLF learning objects in some classrooms produced the following finding:

> "Students highly appreciate the opportunity to learn Mathematics with these digital resources. Not only do they find the materials engaging, but more importantly, they recognise the learning design principles embedded in them (interactivity, cognitive supports, ability to repeat activities, immediate feedback, ability to work at their own pace) as helpful to their learning. Nevertheless, they want the learning objects they use aligned to their age and cognitive abilities." (Clarke & Gronn, 2004:1)

The solution to better matching learning objects to diverse learner needs may lie in creating more complex and challenging learning objects and incorporating appropriate flexible scaffolding, rather than producing series of learning objects that target such specific learning outcomes.

**Conclusion**

The four types of scaffolding - *procedural*, *conceptual*, *strategic*, and *meta-cognitive* - adequately describe the range of scaffolding devices present in the learning objects and therefore form the basis of a useful analysis.

Examining scaffolding is important because the presence and quantity of the various types of scaffolding reflect the level of learning and cognitive demand expected. Over abundance of low level *procedural* scaffolding and unavoidable *conceptual* scaffolding, potentially sets a low cognitive demand and presumes that all learners will need this type of support. The view that all learners will need the same scaffolding for learning tends to produce linear designs, and in some respects is incompatible with the constructivist paradigm. The presence of *meta-cognitive* scaffolding and optional *conceptual* and *strategic* scaffolding, available on demand, reflects higher cognitive demand and the expectation of variation in learning needs. This view of learning is more likely to lead to learning tasks of greater complexity and greater learner autonomy in terms of learning pathways.

A more extensive investigation of the role of scaffolding in learning design should be conducted, but needs to account for the relationships between the intended learning outcomes, learning object design type and age level of the target audience. Understanding the relationships of these variables to the key variable of scaffolding type has the potential to establish a clearer theoretical framework that could be used for further research into the effectiveness of TLF learning objects as learning resources.

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