An online laboratory – is it as good as the real thing?

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Introduction

Processes for development and use of online educational multimedia resources have evolved rapidly over past years. This is fuelled by experience, advances in online pedagogy, financial considerations, and based on responses from education and training markets (Thornton 1999). The availability of support materials online is appreciated by on-campus students, and fully online programs and courses provide opportunities to enter new science and IT education markets (van der Craats, McGovern and Pannan 2002). In general, however, costs of production are under strict control and development favours more generic learning resources that may be readily customised and reused.

Discrete learning objects may be the basic elements in online courseware design, to be used in suitable combinations to serve a variety of purposes depending on the learning context. When appropriately described in terms of the learning objectives they address, they can take the form of a generic activity to be used with content derived from the required discipline or can be a specific content resource. Developers construct, reuse and combine them to create new online learning experiences. Many factors influence the quality of the products, one being the effectiveness of the development process. Understanding the pedagogy and design elements, and the sequence of design, development and evaluation steps in the process is the subject of several projects (ANTA 2001).

Our interest lies in the development and use of a specific category of online learning experience – an online laboratory. Some high cost simulations are available for specific laboratory equipment (Hyltander 2003) but these are not often within the reach of educational institutions or their students on an ongoing basis. Diverse interactive laboratory objects can be found on the Web, some are free to non-profit education providers. Is it possible to create an educationally meaningful and cost-effective online laboratory experience from such existing learning objects? If it is, an effective, optimised and generic process for the creation of online laboratory experiences would benefit future developments.

This paper explores the process of design and development of an online laboratory learning experience. Constant evaluation, iterative development, reuse and combination of existing learning objects are fundamental considerations. A generic development process based on this practical approach is described. Finally, findings arising from creation of a simple online laboratory are discussed, concluding with an exploratory comparison of online and live laboratories.

Planning an online laboratory experience – critical underpinnings

Some fundamental factors govern the likely success of any online learning resource. Both market forces and the current climate of university budget restraint influence our aims and ability to 'meet (y)our student's learning needs while striking the right balance in terms of quality and cost' of the final product (Online-learning.com Consulting 2003). These underpinning factors may influence whether an online development is supported, implemented and successfully deployed, and an appropriate balance during production provides the most beneficial outcome. In brief, they are outlined in brief below.

Pedagogic considerations

Meeting the learning needs of our students is the foremost goal. Major aspects include the:

- learning outcomes required, such as an understanding of the theoretical concepts;
- competency in manipulating laboratory equipment;
- levels of engagement or study, such as novice/proficient/expert; and
- educational contexts for use, such as learning/training/revision/assessment.

Production cost considerations

Managing the cost of production presents constant concern. Sims, Dobbs and Hand (2001) check 'Strategic intent'. This entails deciding on the worth of the project and its scope, such as consideration of possible markets and technology base, characteristics of potential student cohorts, and finding specific design and development strategies that suit the development environment and the intended product. Current wisdom dictates the reuse of existing learning objects (Jacobsen 2001) and that learning objects are created only when necessary and in as generic form as possible.

Product quality considerations

An awareness of quality requirements in the final product leads to proactive evaluation (Sims et al. 2001). Our experience suggests that iterative design and development promote constant evaluation. By developing course material *online* and *in use* the resource is available for inspection and adoption by teacher and learner from its earliest form. The evaluation process is then built-in and well considered and, with incremental improvements occurring, product quality is enhanced progressively.

An exploration of the design and development process

Our university develops online and mixed-mode programs for delivery in culturally, politically and economically diverse international education destinations where, often, well-equipped laboratories are not available. Yet, the students must gain laboratory skills and learn the concepts. Our interest is in devising an efficient process for creating effective online laboratory experiences for these markets.

Our team has extensive experience in online development and is familiar with the cost-benefit analyses performed on strategically funded projects. However, an exploratory study of the process of development of an online laboratory experience was performed with particular attention paid to:

- the evaluation of pertinent Web sites according to the desired learning object characteristics;
- customisation versus design and development of learning objects required for an online experiment; and
- the pedagogy, design, and development of the experimental exercises using the learning objects.

The study explored a simple laboratory exercise, the steps straightforward and short, allowing us to thoroughly scrutinise the development process as it unfolded. The constructivist scenario confronts students with the origin and effects of uncertainty in measurements using simple equipment, such as vernier rulers, micrometers, a balance and burette, as they determine the density of several objects.

The process model

Our study and analysis resulted in the definition of a generic process model for creation of an online laboratory, as depicted in Figure 1. The *tools,* identified with italics in the ensuing text, were generated to assist in the process, and were generalised to enhance the efficiency of our future online laboratory design and development work. Essential features of the process include continual evaluation, encouragement of iterative development, and opportunity to reassess production viability throughout. A brief discussion of this process concentrates on the four key tasks (depicted as rectangles) that are central to its operation, and their associated decision points (shown as diamonds).

Determine strategic intent

The initial task involves a cost-benefit analysis. Details of the online laboratory requirements, its size

and quality are balanced against the cost of achieving it. A *Product usage profile questionnaire* assists developers in estimating how cost effective the design and development can be, considering:

- market potential – current and future markets, such as offshore international, on-campus local and international students;
- university partnerships and collaborative efforts (Tuttas and Wagner 2001);
- product requirements, production costs versus educational benefits; and
- the possibility of generalising the structure and content to enhance reuse opportunity – in other laboratory sessions, topics and science disciplines; for current and future cohorts; for various learning contexts.

Analysis of the responses provides an answer to the question 'Is it worth doing?' A negative outcome leads to the task 'Consider alternative approaches' to online laboratory development, and perhaps an alternate solution. A positive outcome leads to the task of finding useful content sources.

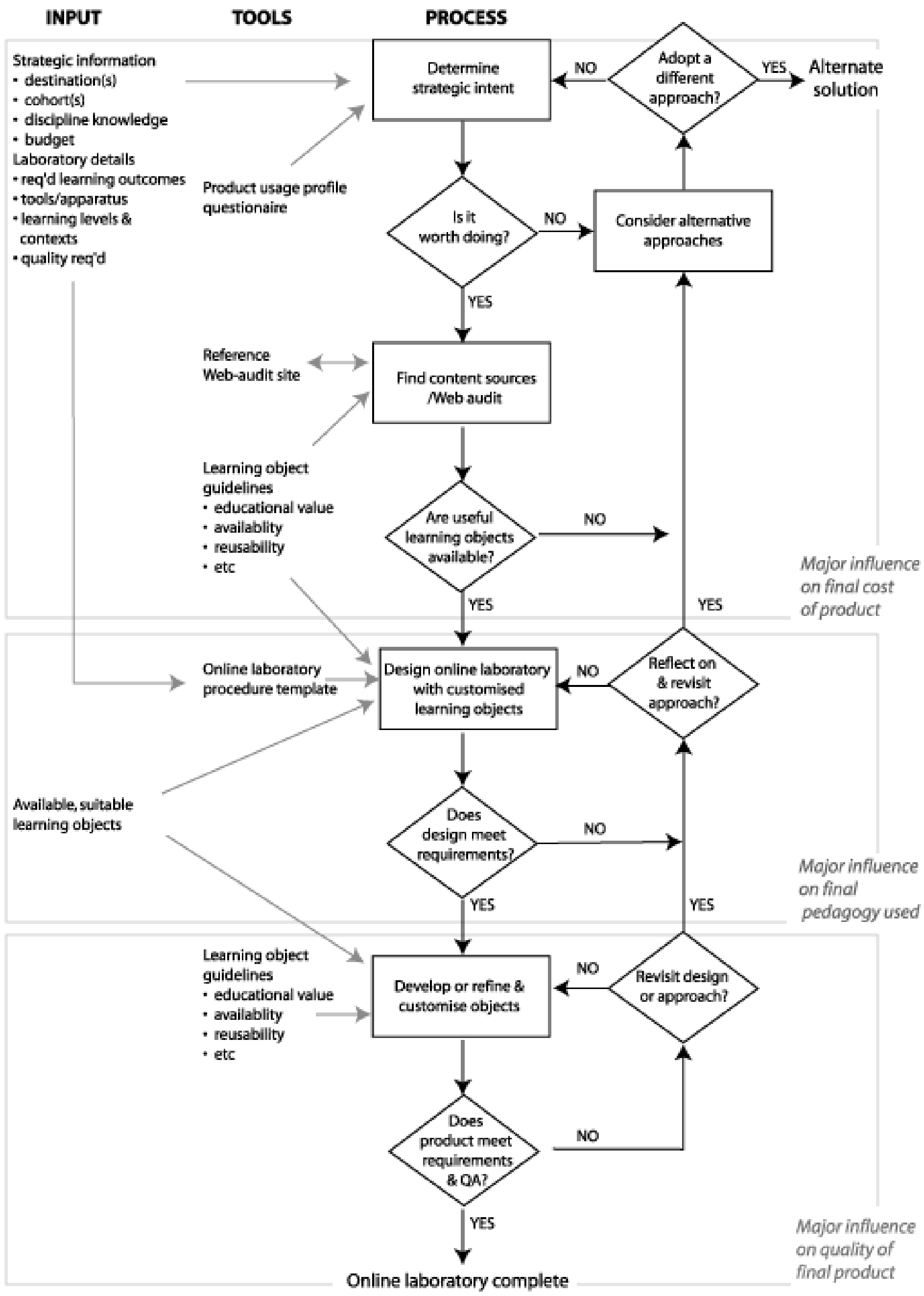

Figure 1. Process model for design and development of an online laboratory learning experience

Find content sources
An initial search of the Web and the *Reference Web-audit site* (created during the Web search in our study) is performed to find learning objects suitable for customisation and reuse. Content, education, and multimedia experts can use the *Learning object guidelines* to assist them to consider pertinent issues such as the object's topic and granularity; educational value, depth, and applicability to several contexts; availability; reusability; interactivity; language use; and visual impact.

If suitable learning objects or combinations of such are found, the task of designing the online laboratory experience starts. If not, alternative approaches to the online laboratory should be considered. This may reinforce the need for the current approach and, possibly, lead to a more expensive solution where several new learning objects must be created. Alternatively, choosing to 'Adopt a different approach?' could lead to a less costly alternate solution by using the available resources and altering the pedagogic approach to achieve the same, or altered, learning outcomes.

Design the online laboratory
The *Online laboratory procedure template* (created in our study, and refined in response to results of a useability analysis performed on a design of the online laboratory experience) is used to assist in creating the online laboratory design, by providing a generic structure. Input includes the 'available, suitable learning objects' found above, along with 'Laboratory details' and 'Strategic information' such as the required learning outcomes, cohort characteristics, education level and context, and the quality required. Designing an online laboratory experience requires that both the learning and the multimedia designs are developed; the latter generally supports the former. When existing learning objects are reused, customisation of their multimedia design may lead to variations in the learning design that would not have occurred with custom-built resources. The *Learning object guidelines* are used to guide such re-design to best meet future needs of reuse and combination of learning objects.

The resultant design of the online laboratory experience is analysed by a consultant peer and, if possible, a student walk-through to provide insight into whether the design:

- of the interface is consistent with the learning design, particularly the learning style(s) supported e.g. constructivism – the degree of user focus, or interactivity, is an important element;
- adheres to the required learning outcomes;
- is pitched at an appropriate level for target cohorts, and considers student support mechanisms;
- allows for use in different learning contexts, and considers the integration of assessment tasks; and
- is of appropriate granularity to allow for reuse in other laboratory scenarios and related topics.

This assessment of the design provides a response to the question 'Does design meet requirements?' A positive outcome is needed to progress to the development task. For a negative outcome, and depending on the magnitude of the concerns, it may be of value to 'reflect on and revisit approach' or simply fall back into the design task to address the concerns identified.

Develop or refine
The *Learning object guidelines* are used again, this time to support the customisation and development work. The aim is to produce an integrated online experience comprising learning objects that may have multiple applications and require little re-programming to adapt them to meet the needs of other contexts. Our preferred development approach is iterative. Following initial customisation, or development, the product is tested, and continued development and refinement occurs when a negative response to 'Does product meet requirements?' is registered. Testing occurs in a graduated manner being based on feedback gained from the development and design team, initially; consultant peers; early use of the online exercise in non-critical aspects of teaching, such as learning support material, pre-labs, revision opportunity, and for students who miss the face-to-face laboratory; and, its use in remedial study. At any stage it is possible to 'Revisit design or approach'.

With its underpinning of constant evaluation, quality has been designed and developed into the product. However, a final Quality Assurance procedure involving formal peer reviews achieves at least two important outcomes, being:

- a formal external perspective of the product, and documentation about potential future refinement, development and use; and
- an increased level of appreciation of the potential of online learning experiences as a consequence of external staff, and student, critical engagement with the online resources.

Influences on cost, pedagogy and quality

A fundamental feature of this iterative process model is the consistent opportunity to revisit and reassess the effectiveness of any of the preceding tasks. Even during the final iterative development stage the opportunity for reassessing production viability is present. This ability to reassess means that decisions about cost, quality and pedagogy, the critical underpinnings discussed earlier, are guided by considerations appropriate to the specific concern irrespective of the stage of production. As a consequence, the process task areas that have major influence and, therefore, carry the burden of responsibility for each of these underpinnings can be correlated as follows:

- final cost of product – determination of strategic intent and finding suitable content sources;
- final pedagogy used – design stage of the online laboratory; and
- quality of the final product – development stage.

Discussion

The process followed in creating an online laboratory experience for our exploratory study provided focus on the pertinent issues. It clarified the goals and how they might be achieved and piloted criteria by which a cost benefit analysis may be performed where the use, adaptation or development of learning objects are considered. Although some relevant resources were found for our simple uncertainty laboratory, they were of limited value and availability, and the estimated cost of customisation prevented their reuse for our purpose. Hence, we reused several in-house objects from previous projects, and created another. It is a concern that few suitable learning objects were found, such as seen in Model Science Software (1997), perhaps reflecting the lack of consistent operational definition of what they are (Oliver 2001) and little uptake of object 'decoupling' (Boyle 2002).

During evaluations of our online laboratory design, the simplicity of the study example proved to be a major advantage in that a useability analysis was practicable. The results highlighted the need for demonstrator assistance where possible, and for some experience in a live laboratory if equipment manipulation, and similar, are required learning outcomes. It is likely that our online laboratory will be the only practice in this topic for some groups of students whereas others will use it in conjunction with the live laboratory, as a preliminary exercise and for reinforcement. It may, in the future, offer a way of testing student pathways of investigation and enable assessment of laboratory competence. Hence, the flexibility in educational contexts and removal of the time constraints often seen in a real laboratory potentially enhance the opportunity for learning. While the degree of realism and animation, and the level of artificial intelligence employed to analyse students' actions is governed by pedagogic usefulness and cost, Herrington, Oliver and Reeves (2003) found that, generally, the more 'authentic' scenarios motivate and encourage learning and lead to better educational outcomes. Our preliminary use of the online laboratory product further indicates that the consistent presence of the underlying theory associated with each learning object encourages an appreciation of the method of equipment use and an understanding of the theoretical basis of its operation.

The generic process model defined as a consequence of this study is yet to be thoroughly investigated to determine its range of applicability and levels of efficacy. Testing of the tools and process will proceed through their use by other staff in development of further online laboratories required for our current markets. The strength of the model is expected to lie in its fundamental shift from the well-worn project approach in that there are two equally successful exits from our iterative process model. One exit yields a strategic, within budget, pedagogically sound alternate solution to the online laboratory experience, the other provides a strategic, on budget completion of a quality, pedagogically sound, online laboratory.

Conclusions

This paper presents a generic process model for the development of an online laboratory experience based on underpinning cost, pedagogy and quality of the final product, with essential elements of continual evaluation, iterative development, and opportunity to reassess production viability throughout. An outcome of interest arising from the exploratory study that produced, and used, this process was the clarification that an online laboratory experience is a different learning experience to that of a live laboratory and has comparative advantages and disadvantages. Although it cannot give the tactile familiarity from working with real tools, and offers limited serendipity, the online laboratory is more adaptable and applicable in diverse learning contexts. At this time the support of demonstrator assistance and some experience in a live laboratory is recommended if equipment manipulation, and similar, are required learning outcomes. These differences mean that the answer to the question ‘Is it as good as the real thing?’ must be ‘It depends…’.

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References

Australia National Training Authority (2001) Australian flexible learning framework for the National Vocational Education and Training System 2000-2004. Brisbane, Queensland: Australasian National Training Authority.

Boyle, T. (2003) Design principles for authoring dynamic, reusable learning objects. *Australian Journal of Educational Technology,* **19**(1), 46-58.

Herrington, J., Oliver, R. and Reeves, T. C. (2003) Patterns of engagement in authentic online learning environments. *Australian Journal of Educational Technology,* **19**(1), 59-71.

Hyltander, A. (2003) Simulation as a teaching alternative: Utopia or reality? *CAL-laborate*, **10**, 9-12.

Jacobsen, P. (2001) Reusable learning objects: What does the future hold? *e-learning Magazine*. [Online] Available: http://www.elearningmag.com/elearning/article/articleDetail.jsp?id=5043 [2003, July 8].

Model Science Software (1997) *Model ChemLab* [Online] Available: http://modelscience.com/products.html [2003, July 28].

Oliver, R. (2001) Learning objects: Supporting flexible delivery of online learning. In *Proceedings of 18th Annual Conference of ASCILITE.* Melbourne, Vic, 453-460.

Online-learning.com Consulting (2003) *Custom online course development or authoring – Courses accredited by Ohio University and Carleton Uni*, Ottawa, Canada [Online] Available: http://www.online-learning.com/consult_development.html [2003, July 15].

Sims, R., Dobbs, G. and Hand, T. (2001) Proactive evaluation: new perspectives for ensuring quality in online learning applications. In *Proceedings of 18th Annual Conference of ASCILITE.* Melbourne, Vic, 509-517.

Thornton, C. (1999) Back to school, web style, *PC World Online*. San Francisco, CA, 1-2.

Tuttas, J. and Wagner, B. (2001) Distributed Online Laboratories. *Engineering Education and Research: A Chronicle of Worldwide Innovations* (iNEER) USA, 1-5. [Online] Available: http://www.zdt.uni-hannover.de/mitarbeiter/tuttas/icee01c.pdf [2003, July 15].

Van der Craats, C., McGovern, J. and Pannan, L. (2002) A five-level approach to the large-scale development and delivery of online programs. In *Proceedings of 19th Annual Conference of ASCILITE.* Auckland, NZ, 681-690.