In an Economy for Reusable Learning Objects, Who Pulls the Strings?

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ABSTRACT

It seems a foregone conclusion that repositories for reusable learning objects (RLOs), based on common standards and supported by suitable search facilities, will foster a global economic market in the production of RLOs. Actual reuse will support producers of high-quality RLOs, and other producers will be unable to compete, i.e. competition within the market will implicitly define the qualities that are needed. This paper challenges the suggestion that this will occur. If the marked is defined as cost versus value, then the set of qualities that distinguishes RLOs from other educational software prohibits the development scalable search engines to search the repositories. At a more sophisticated level of market analysis, it is the needs of the producers, rather than the purchasers, that will define quality in the market. Any attempt to limit this imbalance will, paradoxically, require acceptance of alternative constraints that many may find hard to accept.

Keywords

Reusable learning object, Reconfigurability, Course design, Complexity, Learning Object Economy, Repositories

Introduction

Reusable learning objects (e.g., Polsani, 2003; Downes, 2003; Liber, 2005) allow the cost of initial development to be offset by subsequent reuse in a wide range of different contexts (Nitto *et al.*, 2006). Conformance to a standard should ensure that the same RLO will function consistently in any virtual learning environment (VLE) that supports the same standard. As RLOs can be subdivided and recomposed in different combinations, the potential for reuse in a global market is significantly enhanced (Hodgins, 2002). The development of this market depends on three components. These are a technical and legal infrastructure to support the market, the ability to decompose RLOs to allow for reuse within a different learning context, and a market that supports a community of producers (Liber, 2005) and a community of purchasers. Purchasers should be those reusing RLOs 'at the third level' (Koper *et al.*, 2004, p. 16), where there is no connection between the context of the original design and the context of reuse, other than the RLO itself.

Tompsett (2005) argues that creating complex learning objects is inherently more difficult than decomposing one RLO into sub-components. He argues that two core problems in educational design, consistency within any set of RLOs and sequencing a set of RLOs, are computationally complex. In each case, small examples appear trivial to solve, moderately sized examples require unreasonable computing resources, and larger scale examples are impossible to solve. Thus, as the number of potentially useful RLOs increases and the size of the possible RLOs decreases, it becomes impossible to search for useable sets of RLOs, irrespective of the technological infrastructure or computing power that is available.

This paper considers whether the establishment of a market in RLOs can overcome these restrictions. Educational designers may expect sophistication in teaching students, whereas course delivery, from an institutional perspective, may be more concerned with average effectiveness and economic efficiency (cf. Fletcher & Sackett, 1979). If the delivery of a course using RLOs is cost effective, then finding a 'good' educational design may be unnecessary. This requires, of course, that a market for RLOs exists and that a suitable set of RLOs can be discovered to match the economic requirements. If the conventional view (e.g. Leeder *et al.*, 2004) holds true, then competition will drive up the underlying standards, to the mutual benefit of the institutions, the students and those that produce the best RLOs.

This paper considers the potential for this market to exist. Firstly, taking Porter's basic definition of a market (1985), the paper shows that the searches that are needed to exploit the market are computationally complex. Secondly, simplifying these assumptions in order to remove complexity, it then shows that this undermines what is novel in the RLO model. Finally, providing greater sophistication to the analysis by integrating Porter's model of competitive strategy (ibid.), the paper suggests either that the market fragments, or that the producers, not the purchasers, will control quality.

Background

This argument is directed towards the design of courses that are suitably complex and contingent on the integration of RLOs for their design.

A first proviso is that the courses are to be delivered within an education system in which advanced knowledge is delivered through institutions. The emphasis on advanced knowledge ensures that we are not dealing with relatively simple levels of understanding which can be constrained by additional factors (e.g. a national curriculum or standard assessments). The requirement that knowledge is to be delivered through institutions (e.g. Eraut, 1994, p. 118) avoids an outright rejection of the delivery of codified knowledge, on socio-constructivist principles (e.g. Lave & Wenger, 1991; Brown & Duguid, 1991; Wenger, 1998).

A second proviso is that reuse will only be considered at the third level (Koper *et al.*, 2004) 'at a price'. In a mature market, it cannot be presumed that existing objects will be reused simply because they are placed in a repository (e.g. Walsh, 2006).

A third proviso is that successful course design depends explicitly on the novel, assured integration of RLOs rather than the linking of hypermedia resources over the Internet. Without this proviso, the discussion on RLOs would add little to previous work that has been achieved using Internet protocols (e.g. XML Clark, 1997; Clark & Deach, 1998) and hypermedia/ hypertext models over 15 years, or earlier (Nelson, 1965; Bush, 1945).

Problems that are specific to the current market (see for example, Christiansen & Anderson, 2004) help us to understand why design using RLOs may be difficult now, but such problems could be considered as too detailed, or too specific to remain unsolved in the longer term. The discussion presumes that any transitional problems that occur in establishing a global market have been resolved. If the market is to provide a consistent force to increase quality, then the market must have acquired a degree of consistency, scale and stability for transitional effects to have disappeared.

Reusable Learning Objects and Metadata

The discussion that follows is deliberately generic, so that the interrelationships between some critical aspects are identified. We start the discussion with four principles, which are presented as a technical framework for RLOs in order to avoid arguments over particular standards.

The first principle concerns the relationship between the technical environment and the final 'standard' that is established for RLOs.

1. Any 'final' standard for RLOs will be platform neutral/independent.

This is unlikely to be controversial since all the current standards accept this principle (cf. Johnson, 1998; Jesukiewicz, 2006). It provides assurance that an individual RLO will function with technical integrity on any platform (even if additional equipment may be required). How this will be achieved remains uncertain (Smythe, 2004; CETIS, 2004).

2. Integration of content is assured by conformance to standards at the metadata level.

This principle ensures that 'equivalent' RLOs can be exchanged without losing any educational value that is covered by the standard. This should also be uncontroversial. Although these standards are expected to evolve, there is no indication that this is infeasible (CETIS, 2004; CanCore: Friesen *et al.*, 2002; EML: Manderveld & Koper, 2004; SCORM: Blackmon *et al.*, 2004, etc.).
With these two principles in place, any set of RLOs should be interoperable, and function correctly in any new context, and on any technical platform, independently of the context or platform for which each of them was developed (IEEE, 2002). Failure to achieve this fragments the global market and limits the set of useful RLOs to those that are consistent with each institution's VLE.

The next two principles ensure that RLOs are essential to the design of a course.

3. The standard must ensure that any RLO can be broken down into a number of smaller RLOs, or else is one for which any further decomposition fails to make sense (either technically, or educationally).

This principle distinguishes RLOs from other existing educational resources. It is assured by the use of XML, although, for this analysis, there is no requirement that the decomposition is hierarchical. This principle establishes a key property: each fragment is less tightly bound to the context of its original development (Hodgins, 2002) and, as a consequence, the market will contain a large number of RLOs for which the context of reuse is under-specified.

Finally we require that:

4. It must be possible to identify relevant RLOs to integrate into a course on the basis of searchable meta-data.

This is inherent in any of the current proposals as meta-data is included within each RLO, but a wider range of solutions could be envisaged. The critical issue is that the potential value of any RLO can be represented as static information. If a full assessment requires that an RLO be inspected in detail, then it cannot be claimed that integration between RLOs is achieved simply through the use of RLOs, rather than through some additional factor that is intricately 'designed in' to individual RLOs but which is not coded in the meta-data.

These four principles should be sufficient to ensure, given a suitable technical and legal infrastructure (e.g., Downes, 2003; Koper *et al.*, 2004, et al.), that a global market for RLOs could exist in which:

- a search on meta-data across repositories (e.g. van Assche *et al.*, 2006), or meta-repositories, would identify any possible RLOs that could be used in constructing a course from RLOs.
- individual RLOs that have been 'purchased' can be integrated into more complex RLOs without the need to test that the combination will function as expected.

At this point the concept of 'course design' is deliberately left unrefined. Although many argue that current models are limited (e.g. Kassahun *et al.*, 2006), a more critical issue is whether the market will be of sufficient size to be self-supporting. It is suggested that four assumptions are essential. It will only be necessary to consider what is meant by course design using RLOs if such a market is viable.

A market for RLOs?

Few authors have considered that a market for RLOs might not exist. To clarify this, four critical assumptions are identified on which the rest of the argument is structured. These should be uncontroversial.

The first two ensure that the market is of a sufficient size to allow a choice for most courses to be designed using RLOs.

1. Almost all searches for a *single* RLO, with some search criteria unspecified, will produce multiple solutions.
2. Almost all searches for a *single*, fully specified RLO, which could be used as a self-sufficient component of a course, will fail.

The first assumption ensures that creating a course from existing RLOs will not fail because specific components do not yet exist. The second condition reflects the fact that the majority of components are under-specified. The second condition also excludes the utopian scenario in which any course could be constructed by selecting a handful of learning objects. If this were to be allowed, then it becomes impossible to argue that the success of any course depended on design by RLO, rather than on detailed interrelationships within each RLO.

Once RLOs are available on this scale, then the simplest 'market' principles must also apply. As Porter notes: "Buyers must be willing to pay a price for a product that exceeds its cost of production, or an industry will not survive in the long run" (1985, p. 8). Since the market must reward those that produce 'good' RLOs, two further assumptions are introduced.

The first is:

3. Purchasers must be willing to pay a price for each RLO that allows the producers of good quality RLOs to make a reasonable profit in the long run.

The 'cost' to the institution for using the RLO will need to include this price, together with predicted estimates for technical, teaching and administrative support. The final assumption reflects the reciprocal nature of the market. If a purchaser buys any RLO from the market, then they must be able to associate an 'educational value' (EV) to each possible purchase without detailed inspection of the RLO. This leads to the final assumption:

4. Every purchaser must be able to give an estimated EV for each RLO that is calculated on the meta-data available.

For simplicity EV is assumed to be numerical. Within the argument that follows, there is no need for EV to be expressed in financial terms, nor is there a need to be more precise about how this is calculated. More complicated evaluations of individual RLOs will only exacerbate the decision problem that follows.

The set of principles and assumptions listed above should be sufficient to allow each purchaser to select a set of RLOs in order to construct a course from the global market of RLOs, in which technical and educational effectiveness is assured.

If the market exists, then the market will genetically develop a set of qualities that are, de facto, those that ensure competitive success. The critical question is whether these qualities will be consistent with 'fitness for course delivery' from an institutional perspective, or whether other forces in the market will generate an alternative set of qualities.

Collecting sets of RLOs and the knapsack problem

To assess this argument the economic decision must be analysed in more detail. The fundamental question is: can a cost effective set of RLOs be found whilst only considering the cost and EV of each RLO?

This is implicitly a question of reconfigurability: "the potential of a collection of existing RLOs to be re-configured as a larger, educationally effective part of a course and to integrate with that course" (Tompsett, 2005, p. 446). In the original paper, two educational properties of a set of RLOs were identified, each of which required a search through repository based properties of individual RLOs. Both of these problems were shown to belong to a wider set of decision problems, that are termed 'Non-Polynomial Complete' (NPC, Garey & Johnson, 1990). in order to establish a subset to meet property of the complete set. All NPC problems are equally complex to solve and none are possible to solve in practical terms, irrespective of the computing power that is available (or the speed of any network). The first critical point is to show that this market problem is indeed an NPC problem.

The search that is needed can be modelled as a 'knapsack problem', which belongs to the same set. A knapsack problem, with minor rephrasing from Garey & Johnson (1990, p. 65), requires that:

> "A number of objects can be taken on a journey. Each of them has a certain *value* and occupies a certain *size* in the rucksack - we do not worry, for now, whether they would actually fit together. The problem is to decide if a subset of these can be found that will:

be below *a maximum* size (of the knapsack), but allow you to take *at least* a certain amount of value." (italics as original)

If we draw a parallel between *value* and *EV*, and between *size* and *cost*, then the course designer is faced with the following problem:

A number of RLOs can be purchased to use on a course. Each of them has a certain *EV* and can be purchased at a given *cost* - we do not worry, for now, about other criteria. The problem is to decide if any subset of the RLOs can be found that will:

have a total cost within maximum budget for the course but offer *at least* a certain amount of EV.

From an institutional perspective, it is impossible for the course designer to search across the global market in order to select an effective choice from the full set of RLOs. As the number of useable RLOs increases, and the size of the possible RLOs decreases, then it becomes infeasible to collect economically useful sets of components, irrespective of the technological infrastructure, computing power, or standards that are established. State of the art algorithms (see Tompsett, 2005) fail; ignoring 'other criteria' invalidates the approximations that are applied in the 'best' algorithms (see Appendix A). The only alternative is to place an upper limit on the number of components that can be selected - contradicting principle 3.

At this point we reach a central point of the paper. If the market for RLOs conforms to the principles and assumptions that have been outlined above, then a global search cannot be supported by software, either locally, or centrally within repositories. The 'mathematical' complexity of reconfigurability will persist irrespective of changes in coding such as those envisaged by the introduction of the semantic coding (Tompsett, 1991), the semantic net (Dzbor et al., 2007) or the introduction of peer-to-peer technology (Brito & Moura, 2005).

Contrary to expectations, fragmenting RLOs into an increasing number of smaller components will reduce the possibility that the purchaser can make an effective decision.

In order to circumvent this problem, we will either need to remove the 'mathematical' complexity from the decision problem or add more detail to the analysis of the market in the hope that additional detail will simplify the search (cf. Waltz, 1975).

Simplifying the market

Although scale is the key factor that controls the size of the search, the inherent complexity of this problem is created by the ratio between the EV and the cost of each RLO. Simplifying the EV to cost ratio (EVCR) will remove complexity from the problem. Two classes of simplification: minimal-cost and cost-related-to-value are considered below.

Minimal-cost covers scenarios in which the cost of course design using RLOs is so low that any other approach to course delivery would be dismissed. A universally low cost model covers any scenario in which the price of every RLO is extremely low. This must be dismissed as irrelevant to improving quality. If the market is large, then this scenario treats the actual decisions as irrelevant and removes any possible influence that these decisions will have to improve the quality of the products that are available. Altruism, an alternative to universally low cost, would suggest that a suitably large number of RLOs are made available to the market at an artificially low cost, as the development is benevolently funded from external sources. At the first level of analysis this sounds ideal for both the purchaser, who has little financial risk, and the producer, who has assured development costs. However, it is not the consumer that is directing the market in this case: the critical choices are made by those who fund the development. Any developer that attempts to compete on the 'open market', without initial funding, is immediately placed at an economic disadvantage and so competition is no longer 'open'.

This problem exists even if funding is restricted to the early stages of market development. Assured funding allows a small number of producers to establish a number of RLOs within the market of 'early adopters'. These will provide a funding stream to finance future work – an advantage which is even more critical if the price of the existing RLOs is allowed to rise when external funding is removed. With established teams and procedures, these producers will be able to provide new RLOs to the market with lower overheads for production and financing. These producers can then choose their own strategy to limit any ‘new entrant’ producers (Porter, 1985, p. 131). This could vary, from full exclusion – offering new RLOs at costs that cannot be matched by new competitors, to strategic selection of new competitors in order to provide a ‘cost umbrella’ to increase profitability (‘competitor selection’, 1985, p. 201 ff.). Such strategies are only vulnerable if a significant number of purchasers collaborate to widen the range of producers, and accept the current cost disadvantage as part of a longer-term strategy to broaden the market. Even if the costs for these funded RLOs are not allowed to rise, the market penetration, almost certainly in the most re-useable RLOs, will give these funded producers significant opportunities to select one of a wide range of market strategies (see below) to control the sections of the market with the highest profitability.

Cost-related-to-value characterizes a range of solutions in which the cost is constrained (or calculated by methods that do not introduce further complexity) to fall within specific limits of the EV, or vice-versa. In such cases, only one of the factors needs to be considered as the control factor in selecting a set of RLOs. In the simplest version, the cost of RLOs with equivalent meta-data must be the same and it is tempting to view this as a scenario that sets uniformly high standards. Unfortunately it is equally possible that all RLOs are as ineffective as each other. In the more general case, the cost of any particular RLO must lie between a maximum and minimum value, both of which can be calculated from the EV. However, the producers will then lose the ability to differentiate between their own RLOs. With a maximum and minimum possible cost for each RLO, competition between producers will produce RLOs to either one or both of these costs (e.g. as is currently the case with ‘top-up fees’ in UK universities).

Competitiveness between producers is then based on minimizing the cost of production to achieve fixed standards. This divides the market and, unless any other strategy is in place, forces each producer to adopt a 'cost leadership' strategy (minimizing production costs: Porter, 1985, p. 11; economies of scale: Shapiro & Varian, 1999, p. 25). Whilst this is apparently attractive to the purchaser, the scenario decreases quality overall. The producer must set out to achieve as small a reduction in the cost to the purchaser as necessary, whilst minimizing their own production costs compared with other producers. The benefits to the purchaser are minimal in the short term and contradictory in the long term. As Porter notes, when more than one producer adopts this strategy, the market becomes unstable. The producers undercut each other and the overall quality of what is produced is pushed down in order to maintain a viable level of profit. The only positive outcome for the purchaser is the development of a new market for cheap, low-end products with unreliable quality. Alternatively, both quality and margins continue to be cut until a single producer remains. At this point the cost for the low-end product can increase without any competition to ensure that quality will also increase. Cost-related-to-value does not improve quality from the purchaser’s perspective (cf. Tesco Supermarket in the UK).

Neither of these simplifications: minimal-cost or cost-related-to-value, produces an economic market in which the purchaser controls quality. Both, however, raise questions about the nature of the relationships between producers, and between purchasers and producers.

Improving the market model

It still remains plausible to suggest that a more detailed analysis of the market, providing more economic reality, will remove complexity, without the purchaser losing control over quality.

In order to do so we must move to a model in which each producer adopts a strategy for competition within the market. Porter’s model identifies four strategies that can be used by a producer of RLOs to compete with others in order to gain, or protect market share. Despite the changes that might be considered to have changed in a networked world, the economic principles of these markets remain remarkably similar (Shapiro & Varian, 1999, p. 2). Two strategies act globally, lowest-cost and brand-name. The other two, focus and differentiation, segment the market. Cost leadership has already been discussed and shown to undermine, rather than improve quality. A brand-name strategy is considered next.

A brand-name strategy builds an image of high quality, in direct contrast to the lowest-cost strategy. The strategy is based on trading at a higher-than-market price, on the basis of an apparent value, even if there may be no actual increase in quality. In the most successful cases, the brand name can become a de facto justification of a good decision (cf. 'no-one ever got sacked for buying IBM'). When written in its simplest form, this makes clear that the purchaser is paying a cost for the illusion of quality, rather than for quality itself. More realistically this approach exploits the difference between indicators of quality, rather than quality itself. If it is more efficient to create the impression of higher value, rather than to build higher quality into the RLOs, then a higher level of profit can be maintained. The producer may choose to invest this profit into promoting the brand name, or into improving quality, but the customer cannot affect this decision. Unless the reputation is established, in the first place, by a de facto higher quality relative to cost for the purchaser, and the higher level of profit is used to maintain this ratio relative to other competitors, the effect on the market is to reduce quality relative to cost. This strategy is naturally restricted to a small number of producers, and the value of any margin is expected to be less marked for information, as opposed to material products (Shapiro & Varian, 1999, p. 31).

A strategy based on focus or differentiation, or any combination of the two, responds to differences between purchasers. Focus responds to characteristics that are inherent in the market (Porter, 1985, p. 131) and concentrates on the delivery of products to that sector. This allows internal processes to be optimized to produce a narrower range of products where optimization would not be cost-effective within a global market. For any purchaser within that sector, the scale of the search is proportionately reduced, but these linear effects have no more impact on the effectiveness of the search process than increasing the speed of the underlying computers. Such changes have negligible effect on complexity unless the actual number will always remain low – i.e. the customer has fewer options and less choice. The effect on other sectors is minimal. If purchasers are to control quality, then this can only come from the one remaining approach: differentiation. This final strategy is the most complex and is considered in more detail.

Differentiation requires that "a firm be uniquely able to create competitive advantage for its buyer in ways besides selling to them at a lower price" (Porter, 1985, p. 131). This takes into account factors that are specific to the competitive strategy of each purchaser, rather than those that are common across a sector. If the supplier of an RLO can design their product to meet the needs of a producer and increase the profit margin of the producer in their own product, then the producer of the RLO can demand a higher price for the RLO relative to competitors' RLOs. This depends on the 'use criteria' for each purchaser, i.e. the qualities that allow each one to differentiate themselves within their own market (Porter, 1985, p. 137). If an institution can increase their profit margin on a particular course by selecting one producer of RLOs, rather than another, then it is cost-effective to pay more than the lowest-cost price for an equivalent RLO. This is a symbiotic relationship. Both the producer of the RLO and the course provider must increase their profits, and protect this increase, a form of economic lock-in (Shapiro & Varian, 1999, p. 110 ff.) We shall return to this point later.

The most obvious examples occur at the lower end of the purchaser's value-chain, for example by customizing each RLO to the specific needs of the purchaser at a cost that is lower than would be incurred by the purchaser. Less obvious examples occur where the value is added directly to the upper end of the purchaser's value-chain (cf. 'intel inside'). Porter discusses a number of standard approaches to differentiation, of which three (summarised from p. 135) could be seen as relevant to the market for RLOs. Expressed in terms of how these affect the value-chain for the delivery of a course, these would be: lowering the direct cost of teaching time, lowering the cost of support staff, and lowering the risk of failure. Although each of these seems indicative of an increase in quality, a more detailed analysis needs to be taken to understand the impact of this effect on the global market.

A reduction in teaching time can occur either through reducing the time that is spent on integrating an RLO into a course, or by directly reducing the time that is needed, e.g. with automated assessment. Reducing the cost of integration with part of the course that is not supported by an RLO suggests that a 'gap' exists within the market (contradicting assumption 1). Suggesting that there is a reduction in the cost of integration between RLOs indicates that cost-effective design depends on more than metadata (contradicting principle 4). Reducing the cost associated with running an RLO is evidently advantageous for that particular institution and, as the relationship is designed to be of mutual benefit, differentiation circumvents the search process for that institution. However, within the global market, the effect is minimal. The cost of an RLO may be reduced, but the RLO must still be discovered through the search process by other institutions. The changes will only have an effect on the wider market if the reduced cost reduces the complexity of the search – which is not the case. Since there is no reduction in complexity within the global market, there is no advantage, unless the same improvements can be copied by all the producers (see below).

The second option, lowering the cost of support staff (and facilities) is unlikely to be significant. These costs are almost certain to depend on the underlying technology, and not the RLO itself (principles 1, 2 and 3). Switching costs should be minimal and reduce the risk of hardware/software lock-in (Shapiro & Varian, 1999, p. 116). In specialised fields, some differentiation may occur. For simple anatomy, the low-cost, ubiquitous, 'Anatomy Colouring Book' (Kapit & Elson, 2001) may require far less technical support than a virtual reality model to do the same. However, if the technical infrastructure is available to support a virtual model, then the same technology can be used in a wider set of courses (Székely & Satava, 1999). However, such cases are limited and will have little impact on the overall standards that are established.

The final consideration, lowering the risk of failure, might appear to act as a discriminating factor at the institutional level but is implicitly limited by the design of RLOs. If RLOs conform to the standards, there should be no risk of technical failure (principle 1), or lack of integration with other RLOs (principle 2). Neither should there be any possibility of failure in educational terms, as long as the meta-data is valid (principle 4). The only scope for increased differentiation in this category is that some RLOs will lower the probability of failure in educational terms by factors that cannot be determined from the meta-data. We suspect that this may be the most interesting aspect – but that contradicts principle 4.

However, before we close the discussion on differentiation, we must note that the symbiotic relationship provides an additional limit to the effect that differentiation can have on a global market. As noted above, an increase in profit must be protected for both the producer of the RLOs and the particular institution that is involved. If other producers of RLOs can imitate the same changes in their products, then competition is reintroduced and the added value of the specialization for the producer decreases, or disappears. The same effect applies to the purchaser's market. If every course provider can achieve the same benefit, then the increase at the upper-end of the value-chain is lost and the higher price for each RLO cannot be financed. This implies that both the producer and the purchaser must prevent imitation, through an effective rights management strategy (copyright and patent protection, etc.) Actual 'bitlegging', as Shapiro and Varian comment, is naturally limited; the more effective a 'bitlegger' is at advertising, the more easily they are discovered (1999, p. 92).

Power to the purchaser?

The introduction of a more sophisticated model of the global market suggests that, in almost all cases, the institutions, when acting as independent purchasers, will have only minimal effect on the standards and underlying quality of the RLOs. Only differentiation, as a competitive strategy for the producer, suggests that competition leads to improvements from an institutional perspective. Even then, the institutions and producers involved must act to prevent, rather than support, a wider increase in quality.

Conclusions

This paper reviewed the proposition that good quality would become defined and controlled by the purchasers within a global market for RLOs. On the basis of a minimal set of principles and assumptions, it was argued that the economic decision to select an economically efficient set of RLOs creates a search problem that is impossible to support in software.

This model of the market was then reviewed in two ways. Simplifying the model, in order to reduce complexity, either lowers standards, or allows external agencies rather than educational institutions to define the qualities that are needed. Providing a more detailed analysis of the market cannot reduce the complexity of the search process and, if anything, suggests that the institutions will have even less control over quality. Even though quality might be improved in a limited number of instances, market forces will act to retain distinctions between producers, rather than to promote consistent improvement across the market. Whilst standards in RLOs emphasize uniformity, the economics of the market place react to foster diversity between producers and to fragment the market.

Two issues offer scope for a deeper analysis than is possible here. The first is that both 'cost' and 'educational value' have been left under-specified. This was chosen to emphasize that the argument holds true irrespective of whether these were defined on a global, or local, basis. Contextualising these definitions for each institution will, almost certainly, increase complexity but allow the possibility that quality may still be achieved, from a local perspective, even if the global market cannot be controlled in this way. However, that would suggest that the concept of course-design based on RLOs is contingent on local, non-generic effects. The inter-relationship between market structure, market strategy and context-dependent value will need much more analysis if quality is to imply anything more useful to course designers than conformance to technical standards.

The second issue to explore is the importance of signalling criteria (Porter, 1985, p. 142), indirect indicators used by a purchaser to identify 'good' producers (cf. institutional reputation in filtering a literature search). Signalling criteria cover the additional information, beyond product specification, that is used to build trust between purchasers and producers that each RLO will perform 'as specified'. Assumption 4 may therefore need to reflect this more directly. However, although collection and management of this information is well-understood within recommender systems (Resnick & Varian, 1997), as in MERLOT (2003), the parallel management and control of such information from the producers' perspective would also need to be considered.

Even so, it should be clear that a global market provides no quick solution to defining quality from a purchaser's perspective. This is a new facet of reconfigurability (Tompsett 2005) - integrating individual RLOs into a more complex RLO is categorically harder than taking a complex RLO and fragmenting it into a set of simpler RLOs.

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Appendix A. Good-enough approaches

The standard method to solving knapsack problems follows the approach developed by Horowitz & Sahni (1974; see also Mitchell *et al.*, 2000). In purchasing a set of RLOs, the organisation is assumed to be able to estimate a target ratio (EVCR) between the overall cost to run the course and the overall EV (whatever the mode of delivery). This ratio can then be used to remove from initial consideration any individual RLOs with a ratio that is much worse than this target value. This reduces the size of possible RLOs to search through, though it does not alter the number of RLOs that could be included in a solution. Once a set of potential solutions has been found, a check can be conducted to test whether swapping any of the current 'best set' with some of those that were ignored, would produce a better solution overall.

The validity of this approach depends on the sets of RLOs that are collected on the basis of the EVCR value. A simple example shows that estimating the EV of a combined set is far harder than this. This example is 'trivial' in scale but should suffice to illustrate why the standard algorithm would never work.

Table 1. Selecting resources

Resource	Coverage	EV	Cost	EVCR
A	a, b, c, d	8	8	1
B	a, b	3.6	4	0.9
C	e, f	2.8	4	0.7

Table 1, above, shows the coverage, EV and cost for three resources. The current 'best-approach' model would select the first two resources (A and B) in order to produce the best set with a budget of '12'. Swapping C for B could never be considered as it has the lowest nominal EVCR. Ignoring the other information, i.e. coverage of each resource, misses the duplication of material that has occurred.