Building Blocks of Metadata: What Can We Learn from Lego™?

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Abstract

The idea that metadata, particularly Dublin Core, could be usable as a Lego™-like construction kit has been a popular suggestion for over a decade. In this paper, we first explore what this metaphor originally meant – why the idea is so appealing, and what design lessons we might take from the idea. We take a look at how close we are today to that ideal, looking at examples of real-world metadata design projects, and suggest that at present the situation is often more analogous to a game of Tetris – that is, the construction kit is sometimes limited, time concerns are often an issue, and there is limited opportunity for creativity. We explore patterns of collaboration in existing projects, such as the Scholarly Works Application Profile development. Finally, we ask how what we know about the process of building a shared understanding and formalisation about a domain can help us come closer to the ideal of Dublin Core as an approachable puzzle-game or construction kit.

Keywords: Dublin Core; collaborative development; agile process

1. Introduction

In an article in D-Lib Magazine from April 1999, 'The State of the Dublin Core Metadata Initiative', Weibel described the principle that

> different varieties of metadata will be elaborated by stakeholder communities, and the metadata architecture should support the snapping together of metadata modules just as Lego™ blocks are snapped together to form compound structures. Enabling the superficially simple child's plan of building with Lego™ building blocks requires surprisingly precise and complex specifications and manufacturing processes[…]. The reward for a unifying architecture […] has been interoperability […] in spite of broad "semantic" variation in the blocks.

This idea holds a broad appeal; indeed, a similar metaphor is often used. Lynch (2010), for example, lists Lego™ along with Playdoh ™ and Nintendo™ as appropriate metaphors for the building blocks of good learning design. The metaphor was critically discussed in the context of learning objects by Wiley (2000), for whom it constituted a limiting factor in comprehension of the real potential and limitations of systems permitting combination of learning object systems. It is based on well-known practical research. Resnick (1990) describes the real-world use of Lego™ and LOGO as a practical design and learning environment illustrating engineering and mathematical concepts, highlighting the following aspects: 1) putting children in control; 2) offering multiple paths to learning; 3) encouraging a sense of community, enabling children to share (and critique) each others' ideas, designs and constructions. Martin (1994) provides an in-depth analysis of Lego™ as a core technology in a design-rich learning environment.
In the context of Dublin Core (DC), the metaphor suggests a vision of usage that supports:

- Accessibility: Low initial barrier to entry – superficial simplicity.
- Exploration: planning, constructing, taking apart and rebuilding with little or no overhead.
- Playing: the stakes are low, and the metadata architects – the players – are encouraged to explore the problem space without too much concern about what is 'right' or 'wrong'.
- Positive feedback: the architect knows when he/she has achieved something.
- Goal-based scenarios: a collaborative goal structure supports a process of construction.

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We might also refer to the possibility of progressively more complex stages of construction, constructing building-block houses, cars, train lines, and cities. Lego is a structured, progressive activity, with new challenges at each level of development.

In this paper, we begin by exploring in the abstract what it means to build a game that supports a learning or development process. We ask what it might mean to build a Dublin Core that supports exploration, experimentation, successive challenges and rewards, and we identify examples of work that approaches this goal. We take a look at the processes of development of metadata structures in Dublin Core, and compare to collaborative gameplay. We draw out a set of strawman design principles, and describe our ongoing work in this area.

1.1. What can we learn from game design?

Characterizing the process of building a metadata representation in terms of a game may have real advantages. An immediate clue to the attractiveness of the Lego metaphor comes from a TEEM report on the educational use of games (McFarlane et al, 2002), which notes that 'There is a widely held view that games software is capable of developing a degree of user engagement which could be usefully harnessed in an educational setting.' That is, games may be complex or detailed or time-consuming, but they are not perceived to be a chore.

The idea that games have something to tell us about the design of enjoyable interfaces, and by extension processes, has a venerable and respectable history. Malone (1982) explored the appeal of computer games, and drew out several lessons regarding features that can make other user interfaces interesting and enjoyable to use. The heuristics included the need to set a goal; to provide a variable difficulty level – that is, offer successive layers of complexity; to provide a form of score-keeping; to embody systems with metaphors that the user already understands; to provide an optimal level of informational complexity; to use well-formed knowledge structures, and introduce new information where existing knowledge is incomplete, inconsistent or unparsimonious (e.g. inadequately clearly defined).

Later research has added a great deal to this viewpoint, including a large number of caveats. In the last decade in particular, the idea that computer games can be useful tools for education has been popularized and widely explored. The results have been discouraging for a number of reasons; edutainment is often too simplistic, repetitive, poorly designed, and monotonal, and it may leave the user feeling patronized (Kirriemuir & McFarlane, 2004). The lure is the promise that players may put as much effort and concentration into educational games as they do into computer gaming. Realistically, exploration of game playing behaviour may be most useful in user modeling, helping to describe the user's expectations.

Perhaps the most significant finding summarized by Kirriemuir & McFarlane is the insight that creating something that *looks* like a game does not necessarily result in something that has the motivational power of a game. The required components of the gameplay experience are less visible. Many experiments in the area led to equivocal results, such as those reported by Elliott et al (2002); their software, designed to appeal to students with no love for learning mathematics conventionally, depended on aesthetic and entertainment appeal to encourage students. The results indicated that a pseudo-3D environment added unnecessary confusion and complexity; that students' expectations of 'game' software were difficult to meet; that the software was not 'fun'; and that, as the authors concluded, 'creating a motivating 3D game that meaningfully enhances learning is a difficult task.' De Byl (2007) puts the difficulty down to 'the lack of content and pedagogy knowledge on behalf of the games companies[,] the lack of technical ability in educators to create such application', and games companies' limited interest in designing games for a smaller audience.

The research acknowledges that there is more to a game than look and feel. Other researchers have confirmed Malone's early findings, which highlighted the elements of fantasy, challenge and curiosity. Games are about challenge and process (de Byl, 2007) – that is, constructivist learning. The component that governs all others is the interplay between challenge and

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achievement: games need a challenge, rules, context and feedback, and a little mystery – to engage the curiosity – can be advantageous (Frank, 2007). To function well in supporting a serious training objective, the scenario must be well-chosen, as well as relevant to the player. Frank observes that such games exist in a context; the teacher, library, or other infrastructure is part of the process too. There is a set of dependencies; if the rules are too complex or ill-understood, nothing can be achieved, and motivation is lost. If there is no challenge, there is no motivation. If the activity seems irrelevant, it may not hold the attention of the player – and what is learned may not be easily transferable to the real world.

The design of collaborative edutainment complicates the problem further, as the game designer needs to consider not only how to retain motivation of an individual player, but how to encourage groups to work together. Effective collaboration does not result automatically from the use of collaborative learning or working environments (Arvaja et al, 2002). Even were it to do so, free collaboration does not systematically produce learning (Dillenbourg, 2002). For this reason, computer-supported collaborative work often involves well-defined scripts, that is, a series of instructions prescribing group formation, interaction and problem-solving. *Epistemic scripts* - structured learning processes designed to support learners in their tasks - may be supplemented by *social scripts* (Hamalainen, 2006). These are designed to enhance team cohesion and collaboration.


FIG. 1. Card Sorting

To test the game concept a simple process for naïve users to develop vocabularies was developed: a card sorting 'game' approach using manual (pen and paper) recording and organizing of terms, developed from paper prototyping concept modeling (Tonkin, 2009). This provided a simple and accessible methodology that did not require specialist process knowledge. The participants just contributed their personal knowledge of a given subject for which the vocabulary was being developed, with simple rules to apply at each stage. Comparing this approach to formally architectured construction of vocabularies, this simplified approach showed advantages for engagement and (initial) development, without the complexity inherent in more formal approaches, although more complex structures could be introduced later in the development process. Overall it provides a simple way to explore the development and collaboration involved in building a vocabulary.

In summary; the game design metaphor leads to a process that gives the users something they wish to achieve, while solving a puzzle or telling a story, and engenders a non-competitive environment that supports collaboration.

1.2. Learning from Lego™?

Building structures using construction toys such as Lego™ can readily be viewed as a good match with many of these characteristics. Structures built can vary in complexity from the very simplest to the most intricate, with more complex building blocks offering the ability to add real-world functionality to the model. Each new stage depends on an understanding of the levels that came before. New information is offered, example by example, as new types of building block are added to the collection. New complexities also arise; not all blocks can support advanced functionality, and so a more advanced model of the system of blocks being used in construction is developed over time. According to Resnick (1990), building blocks can also be used as a component in a collaboration-rich environment, although the conditions required for this to occur are not clearly articulated in the original study.

1.3. The metadata development game

The construction-toy metaphor is a rich one; the design principles presented above mostly appear

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to be very relevant to the aims of any interface, toolkit or construction kit designed to support either the process of familiarizing oneself with Dublin Core in general, or the specific aim of building a metadata structure designed to fulfil a user-specified aim. It is the authors' assertion that the latter aim in particular benefits from comparison with a multi-level puzzle game. There are many steps separating the initial stages of user requirements analysis and the creation of a formal model, each one requiring knowledge of rules and relevant background information, and it would not be surprising if users of Dublin Core found the resulting process, in actu, to be too complex to justify the goals.

In the following section, we compare the current state of Dublin Core to this ideal, and the extent to which the ideal is really relevant to the DC metadata landscape, examining the macro-process and how it is supported. Presentation is, after all, an implementation detail. If the present architecture is able to support the idea, then the lion's share of the work is done – but the point raised by Frank (2007) regarding the strong link between the design of a game and the context in which it is used means that it is difficult for either to exist without the other.

2. Building with blocks of metadata

2.1 A pathway into Dublin Core

The process of developing DC metadata is data-intensive and depends on specialist knowledge, both of the problem space and of the various standards, tools and representations available to the user. The current situation requires a large initial investment of time, thus violating Malone's principle that well-defined knowledge structures should be used, and that new information should be introduced where existing information is incomplete or inadequately defined. The development process, on the other hand, is malleable, and can be adapted to better suit different classes of user, from beginners – who are required to discover the characteristics of Dublin Core as they work towards achieving their own goal – to experts, who know all the short-cuts.

Putting aside the complexities of the DC Architecture, about which much has been written in Dublin Core conferences and other forums, the fact is that these processes, being knowledge-intensive, will benefit from easy availability of information about existing developments in Dublin Core and related standards, Semantic Web, MARC, LOM, etc. This need is partially answered via availability of documentation, but this is centralized, usually reflecting a register and lexicon specific to that community, and hence is not always accessible to the user. A well-supplied metadata construction kit, like a well-supplied toybox, should contain bricks of all types, colours and levels of complexity – from the simplest shapes up to Lego Mindstorms™.

2.2 Architecture

A great deal has been published regarding the development of an architecture capable of supporting flexible application of DC metadata, and we will not attempt to replicate it here. An introduction is available at Weibel (2010). However, it is perhaps worth highlighting one aspect of the present architecture - the interoperability levels designated for Dublin Core metadata (see Fig. 2).

4: Description Set Profile Interoperability. Shared formal vocabularies and constraints in records
3: Description Set syntactic interoperability. Shared formal vocabularies in exchangeable records
2: Formal semantic interoperability. Shared vocabularies based on formal semantics
1: Shared term definitions. Shared vocabularies defined in natural language

FIG. 2. Interoperability levels for Dublin Core metadata

According to Nilsson et al (2009), these represent 'evolving assumptions which over the past decade have led from fifteen elements to the Singapore Framework for Dublin Core'. They represent an appropriate terminology defining various degrees of interoperability with DC. These

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levels appear to be graduated in terms of increasing complexity and formality; if each graduation represents an evolution (that is, advancement, or increasing maturity), then perhaps this is the an appropriate structured progression for the DC metadata game.

2.3 Collaboration: evidence from metadata development processes

Intuitively it may be assumed that provision of a collaboration enabling environment will both provide space in which users can collaborate and engender more or less equal contributions from participants. However, as we shall see, examining extant systems shows that levels of collaboration depend on perceived ownership of environment / process (rather than ownership of the resultant 'product'). Although we will also see that more even collaboration can be seen in environments not 'designed' for strictly collaborative development.

The SWAP application development process took place on a wiki, with contributions from a group of interested individuals. As described (Allinson, 2008), 'We […] assembled a working group of invited experts and began to develop deliverables in the open, collaborative arena of the […] wiki' Using the IBM visualization software, first described in (Viegas et al, 2004) we can explore the development of the Mediawiki site on which the development took place (see Fig 3).

These visualisations are history flow diagrams, which are designed to reveal patterns of collaboration in a variety of scenarios. The horizontal axis is time, and the vertical axis displays the document structure at any given moment - so it represents the evolution of the page, discussion or structure over time. The diagram shown in Fig 3, for example, contains contributions from two individuals, which when the diagram is displayed in colour, clearly shows individual contributions, colour-coded in contrasting colours. As the wiki page displayed here is altered (mostly by adding content) over time, the page length can be seen to increase - this is the height in the y-axis. In this example, the two contributors consist of one who initiates the article, and a second, who provides almost all of the subsequent updates to the page.

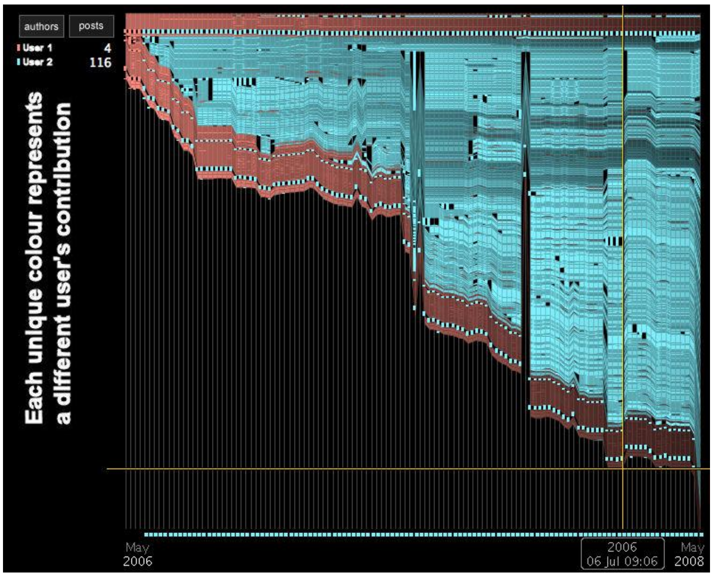

FIG. 3. SWAP collaboration (Mediawiki)

On the face of it, there is little or no collaboration involved here. Only two individuals have made changes to the page. On closer investigation, however, it turns out that in this instance, the wiki was merely a content management system. Collaborative discussion happened in two forums: a) in meetings, records of which are not publicly available and b) on a closed-access mailing list (see Fig. 4). The mailing list discussion (see Fig. 4) showed that over half of the individuals named in the project actively discussed the topic in this forum (each colour represents

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a different individual; user identification strings have been shortened for brevity).

It is also interesting to note as an aside that emails from any given individual tend to appear in bursts, perhaps because several threads are responded to at any given session – a consequence of the asynchronous nature of email. The evidence suggests that the majority of active collaboration occurs either offline or in forums such as mailing lists.

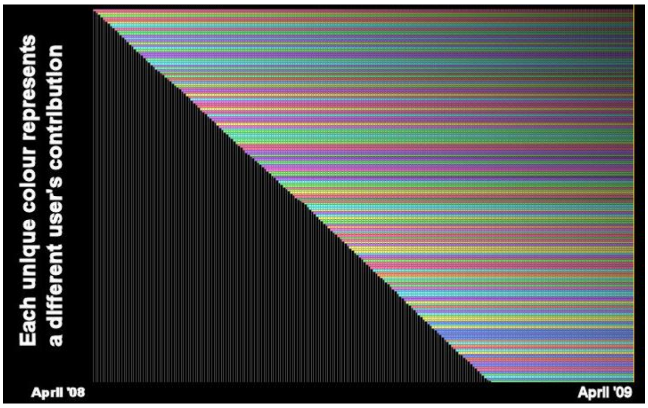

FIG. 4. Discussion on the mailing list (note: this graphic does not indicate the scale of individual contributions, merely the number of contributions and the temporal order in which they occur).

Investigating the RDA development work that took place on the metadataregistry.org site, demonstrates a similar phenomenon. For example, the RDA Group 1 Elements registered on the metadataregistry.org site developed in the manner shown in Fig. 5. as can be seen from this, three individuals actively took part in updating the element set available on the registry. This again suggests that active collaboration/discussion is primarily happening in another forum, but this does demonstrate sustained bursts of activity from several users. Although the metadata registry is not immediately thought of as a collaborative workspace, these findings do suggest that there is potential for it to be used in this manner.

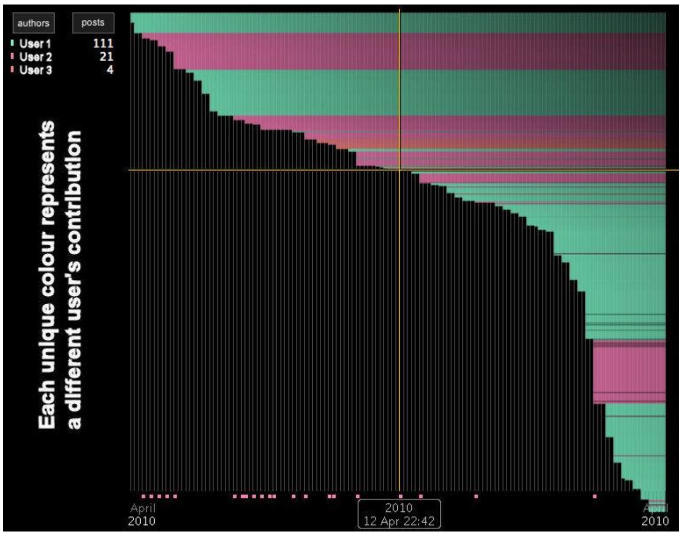

FIG. 5: Development of the RDA Group 1 Elements (2008-2010).

To conclude this section, we note that platforms that are understood as collaborative environments do not necessarily exhibit that behaviour, while others do exhibit elements of collaborative development in practice. We suggest that visualisations such as an appropriate

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History Flow diagram for a given forum can be a useful mechanism for exploring degrees of collaboration, and that this may be a useful resource for those developing platforms that are intended to encourage collaborative work.

3. Metadata construction kits

3.1 Populating the toybox

One role for the metadata schema registry, essentially a multilingual, user-friendly, and persistent index of terms (Heery & Wagner, 2002) (Hillmann et al, 2006), is to provide a unified interface impartially describing a broad collection of available building blocks and their characteristics. The extent to which current registries achieve this is related to the architectural discussions mentioned earlier; as we are exploring possibilities at present, we will take it as read that an exhaustive collection of adequately documented and defined resources is both possible, achievable and potentially available to any design process using these building-blocks as design components.

3.2 Goals and processes

In Dublin Core, the construction-kit approach has most consistently been applied in the creation of *application profiles*, introduced by Heery and Patel (2000), and described by Hillmann et al (2006) as 'entities that provide the means for selecting terms from disparate attribute and value spaces and defining their usage for a specific discourse or practice community'. Various interfaces, including a Java-based client tool (Tonkin & Strelnikov, 2009) and a number of web-based tools, such as the prototype described in (Tonkin & Strelnikov, 2009b), have been designed on the basis of metadata registries to support this activity. Formally, the creation of application profiles is now supplemented by the Description Set Profile. DSP is a simple constraint language for Dublin Core, based on the Abstract Model and formalized within the Singapore Framework (Nilsson et al, 2007). For this purpose, a wiki syntax has been provided, so the later stages of an application development may appropriately take place on a wiki. However, the DSP explicitly does not cover human-readable documentation, vocabulary definition and version control; these development processes and facilities are to be handled elsewhere.

However, the majority of tools are designed with a single specific task in mind – for example, formal encoding of a predesigned element set in order to enter it into a metadata registry for reuse. This is not necessarily problematic, but implies that these tools are unlikely to be appropriate for exploration of the problem space – rather, their design assumes that the user is already familiar with a generally accepted process of development and publication. We suggest that there is a space for software designed to support a design-rich learning environment which, like Resnick's design testbed, more directly supports user-led, exploratory introduction to Dublin Core as it exists today.

Through the development of the MRVoBI prototype described below, we developed a process model for the early development of an application profile: progressing from the initial collection of user requirements to collection of relevant terminology, followed by the development of relevant conceptual models; following this, users are introduced to the registry. This acts as a knowledge base that can be drawn upon as a resource to be used as the data structure is further developed towards the initial rung of the Dublin Core interoperability ladder. Much of the groundwork required in the development of an application profile may be completed on a relatively informal level.

3.3 Toys, games, and metaphors

Manipulable visual representations of various types exist for metadata structures, from UML to data structure diagrams, but using these effectively can be difficult. For example, structural variations rendering a data structure formally invalid may be temporarily introduced in early stages of data model creation. The use of interfaces that are forgiving of invalid input may be

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preferable at early stages of development than enforcing rules that are not yet understood or have not yet been introduced to the user, since this can be frustrating. An alternative is the discovery and use of a metaphor that affords relevant rules, since this means that the user is much more likely to recognize these rules without a formal introduction to the area. Various approaches have been taken to presenting metadata as a resource for reuse, relatively few of which depend upon familiar metaphors. One exception is card sorting, which is used primarily for the purpose of exploring site navigation and classification of existing resources, but may also be used for developing metadata structures (Tonkin, 2009). Another is the file/folder metaphor, a visual form of which is familiar to a large percentage of desktop computer users. Taking this as a starting point, exploring simplified diagrammatic representation, and combining it with the experience of the card sorting vocabulary building game (earlier), led to the concept of the MrVoBI environment as a generalised interface for development of terms and sets.

3.4 The MRVoBI environment

The MRVoBI (Metadata Registry Vocabulary Builder) interface was designed to support the process of building a conceptual model (Tonkin, 2009), and was presented as an initial demonstrator at DC-2009. Since this initial version was built and tested, a great deal of additional functionality has been added, including the following:

- Adaptations designed to enable a heterogeneous and distributed user population to make use of the prototyping software in a variety of configurations, via interfaces optimized for joint (classroom or meeting) use.
- An effective version control system, including aspects geared towards enabling an informed approach to collaborative development; a sense of awareness of other participants is required for effective collaboration (Tang, 1991), as well as shared goals and achievements.
- Node-by-node comparison between model versions enables participants to quickly and easily visualize the changes that have been made at each stage.
- Interoperability between the MRVoBI system and the metadata schema registry backend enables users building a data structure to seek ways of linking the structure that they have developed with existing formalisations, which is to say, to begin to explore a more complex metadata representation than the informal, human-readable description with which they begin.

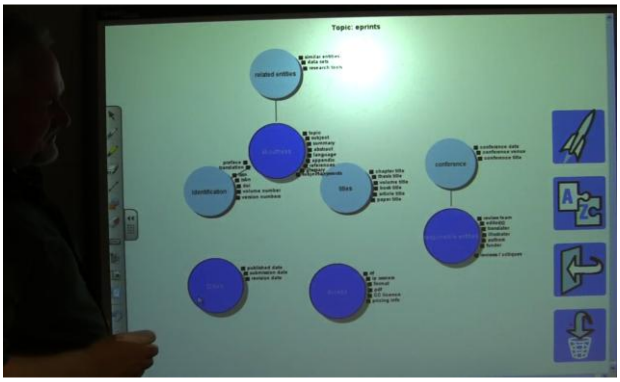

FIG 6: Developing a concept model on an interactive whiteboard

MRVoBI makes use of several well-known metaphors such as card sorting and a modified form of hierarchical structuring, enabling cross-linking between structures. The process is designed to be as accessible as possible to users who are unfamiliar with the processes behind vocabulary building and knowledge structure development. As such, the formal process laid

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down by the Singapore Framework does not come into play until the later stages of building an application profile, for example. The user is led through an iterative development process, which is intended to assist development of fit-for-purpose structures in a limited timeframe.

It is perhaps inevitable that a time-limited process will not permit all criteria or requirements to be optimally met, by comparison to a broader and more formal approach. In particular, it has been suggested that an approach based on application of a knowledge base (registry) to a newly defined problem is likely to encourage users to reuse what is given from the existing framework with scant regard to the details. Somewhat like a game of Tetris; anything that appears to be more or less right may be fitted in to fill a perceived requirement. On the one hand, this meshes closely with the intended use of application profiles (Heery & Patel, 2000), but there are legitimate questions to be asked about validation and evaluation processes, for example, providing data about the fitness of the structure for that reuse. The risks include semantic drift and misuse (Wang et al, 2010).

This software is currently the basis for a series of observational studies intended to characterize effective collaboration in development of conceptual structures. We expect these studies to provide a better understanding of the interactions that take place between users, highlighting the problems and means of resolution that take place in the design process.

4. Conclusion

The authors of this piece are aware that they are guilty of the (hopefully forgivable) sin of knowingly overloading a metaphor. The comparison, however, will be familiar to many; in this paper, we have taken it as a starting point, exploring the enduring appeal of the metaphor; investigating the present state of affairs; and exploring applicable advice that may be taken from the comparison– in interface design, and in effective dissemination. By taking lessons from educational game design, we can discover more about what we can do to support users in coming to grips with an increasingly complex environment – but perhaps the most important message of this metaphor is this: a complex endpoint does not have to involve a high initial learning curve.

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