A Design Quality Learning Unit in Relational Data Modeling Based on Thriving Systems Properties

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Abstract

This paper presents a learning unit that addresses quality design in relational data models. The focus on modeling allows the learning to span analysis, design, and implementation enriching pedagogy across the systems development life cycle. Thriving Systems Theory presents fifteen choice properties that convey design quality in models integrating aspects of aesthetics, the more subjective phenomena of satisfaction; a quality perspective more expansive than that usually found in software engineering, the traditional "objective" notion of metrics. Recent IS curriculum guidelines relegate software development to elective status confining design pedagogy into smaller and smaller pockets of course syllabi. Where undergraduate IS students may once have practiced modeling in analysis, design, and implementation across several courses using a variety of languages and tools, they commonly now experience modeling in two or three courses in at most a couple of paradigms. And in most of these courses their modeling focuses on acceptable syntax rather than achieving design quality in information systems. Learning design quality may once have been an osmotic side effect of development practice, but now it must be a conscious goal in pedagogy if it is to be taught at all. This learning unit is intended as an adaptable framework to be tailored to the coursework and the overall objectives of specific IS programs.

Keywords: design quality, design, relational data modeling, IS curricula, IS pedagogy

1. INTRODUCTION

Over the past decade computing curricula have been repartitioned with the permeation of computing across disciplines and society. (Shackelford, Cross, Davies, Impagliazzo, Kamali, LeBlanc, Lunt, McGettrick, Sloan & Topi, 2005) There are now 5 major guidelines that subdivide curriculum in the computing discipline. (Soldan, Hughes, Impagliazzo, McGettrick, Nelson, Srimani & Theys, 2004, Cassel, Clements, Davies, Guzdial, McCauley, McGettrick, Sloan, Snyder, Tymann & Weide, 2008, Diaz-Herrara & Hilburn, 2004, Lunt, Ekstrom, Gorka, Hislop, Kamali, Lawson, LeBlanc, Miller & Reichgelt, 2008, Topi, Valacich, Wright, Kaiser, Nunamaker, Sipior & de Vreede, 2010) The co-location of IS curricula in schools of business further exacerbates the pressure on pedagogy as accreditation bodies further constrain the scope of coursework by compressing systems development into smaller and smaller pockets of course syllabi. (AACSB, 2010, EQUIS, 2010) Where undergraduate IS students once may have practiced modeling in analysis, design, and implementation across six or more courses in a program using a variety of languages and tools, they commonly now experience modeling in four or fewer courses in at most a couple of paradigms. (Waguespack, 2011a) And in most of these courses their modeling decisions focus on acceptable syntax rather than principles representing and
communicating concepts of quality in information systems. Where learning design quality may once have been an osmotic side effect of development practice it must now be a conscious goal in pedagogy if it is to be taught at all.

At the same time industry and academia persist in their lament over the paucity of focus on quality in system design first sounded more than four decades ago (Dijkstra, 1968) and echoing consistently since as in (Denning, 2004, Brooks, 1995, 2010, Beck, Beedle, van Bennekum, Cockburn, Cunningham, Fowler, Grenning, Highsmith, Hunt, Jeffries, Kern, marick, Martin, Mellor, Schwaber, Sutherland, & Thomas, 2010)

This paper presents a learning unit that teaches quality design in relational data models. The focus on modeling allows the learning to span analysis, design, and implementation enriching pedagogy across the systems development life cycle. Thriving Systems Theory presents fifteen choice properties that convey design quality in models integrating aspects of aesthetics, the more subjective phenomena of satisfaction; a quality perspective more expansive than that usually found in software engineering, the traditional "objective" notion of metrics. This learning unit is adaptable to the coursework and objectives of specific IS programs. The paper presents: a brief overview of design quality, properties to assess design choices, the relational ontology; and a discussion of how each of the design choice properties express quality through the use of relational data modeling constructs. Finally, there is a description of how the learning unit has been integrated in data management syllabi with a comment on its efficacy. A parallel treatment of design quality pedagogy applied to the object-oriented paradigm may be found in (Waguespack, 2011b).

2. WHAT IS DESIGN QUALITY?

Quality is an elusive concept, shifting and morphing on a supposed boundary between science and art: objective, engineering characteristics versus subjective, aesthetic observer or stakeholder experience. International standards of quality reflect the challenge of defining quality by offering a variety of perspectives (as gathered here by Hoyle, 2009):

- A degree of excellence (Oxford English Dictionary)
- Freedom from deficiencies or defects (Juran, 2009)
- Conformity to requirements (Crosby, 1979)
- Fitness for use (Juran, 2009)
- Fitness for purpose (Sales and Supply of Goods Act, 1994)
- The degree to which the inherent characteristics fulfill requirements (ISO 9000:2005)
- Sustained satisfaction (Deming, 1993)

(Waguespack, 2010c) asserts that the quality of systems revolves around two primary concepts: efficiency and effectiveness defined as follows (New Oxford American Dictionary):

Efficiency [noun]- the ratio of the useful work performed [...] in a process to the total energy [effort] expended

Effectiveness [noun]- successful in producing a desired or intended result

These two concepts appear primarily quantitative and therefore objective. In and of themselves they may well be. Portraying efficiency using a convenient interpretation of "work" and "effort" is genuinely objective. "How many" or "how much" or "how often" often depicts efficiency. But, when we ask "Is it enough?" apparent objectivity fades away.

Likewise, the supposed objectivity of effectiveness relies upon the tenuous phrase, "desired or intended result" defined as

Intention [noun]- have (a course of action) as one's purpose or objective; plan

Effectiveness (like efficiency) is a correspondence between a system and its stakeholders' intentions. Assessing effectiveness depends on comparing "what is" to "what is intended." While the former may be expressed quantitatively the latter presents challenges: clarity of conception, mode of representation, scope of contextual orientation, and fidelity of communication to name but a few. Indeed the notion of effectiveness is complicated when we contemplate identifying and quantifying the stakeholder(s) intentions objectively.

The indefiniteness or imprecision that characterizes stakeholder intention(s) is generally not a concern if an observer is asked to assess the beauty of something – an assessment generally conceded to be subjective.
A detailed or even explicit intention is not expected in assessing beauty – beauty is most often perceived as an experience of observation rather than a system analysis.

Most people commonly accept beauty as subjective and exempt from specific justification or explanation – “Beauty is in the eye of the beholder.” and “You’ll know it [beauty] when you see it.” This absence of or difficulty in forming a quantitative justification of beauty is often the basis for categorizing artifacts or processes as products of art rather than of engineering. And therein lies the presumption that the aspects of design quality that we label objective and those we label subjective are somehow dichotomous. They in fact teeter between objectivity and subjectivity depending on the degree of granularity that observers choose to employ in inspecting not only the artifact but also their own disposition toward satisfaction relative to it.

3. AN ARCHITECTURAL INTERPRETATION OF QUALITY DESIGN

We will never be able to absolutely define design quality because of the relativistic nature of satisfaction in the observer experience. But, our students must still face design choices. So, as IS educators we must provide a framework for them to develop and refine their individual perceptions and understanding of systems quality. The taxonomy of design choice evaluation proposed in Waguespack (2008, 2010c), the 15 choice properties, is just such a framework. (See Appendix A.) Choice properties derive from Christopher Alexander’s writings on design quality in physical architecture. (Alexander, 2002)

Choice properties address the process of building, the resulting structure, and the behavior of systems as cultural artifacts. Every design decision, choice, contributes to the aggregate observer experience: either positively or negatively. Each choice exhibits the 15 properties with varying strengths or influence that impact the resulting observer satisfaction. The confluence of property strength results from the coincidence of the designer’s choice with the collective intention of the stakeholders. The combination of all choices with their respective property strengths results in the overall, perceived design quality. Many of the properties are design characteristics long recognized in software engineering (i.e. modularization, encapsulation, cohesion, etc.). But several reach beyond engineering to explain aesthetics, the art (i.e. correctness, transparency, user friendliness, elegance, etc.). An example of the effectiveness of choice properties in explaining the design quality of production systems is reported in (Waguespack, Schiano & Yates, 2010b).

4. THE ONTOLOGY OF THE RELATIONAL PARADIGM

Illustrating design decisions in the relational paradigm can be a challenge. The idiosyncrasies of data modeling syntax often obscure the intention and/or the result of a design decision. For that reason the learning unit presented here uses a paradigm description independent of programming language, the relational ontology, found in (Waguespack, 2010a) and excerpted in Appendix B. The graphical outline of the ontology is Figure 1 below.

Figure 1 – Relational Ontology

The ontology captures the elements of the relational paradigm eschewing the obfuscation that usually occurs with programming language syntax examples. At the same time an experienced IS teacher can readily translate the ontological elements into a relevant programming or modeling dialect.

5. CRAFTING RELATIONAL MODELING CHOICES THAT STRENGTHEN PROPERTIES OF DESIGN QUALITY

This section, the heart of the learning unit, enumerates the 15 choice properties as defined in Waguespack (2010c) illustrating how modeling choices in the relational ontology can express design quality. In this space-limited discussion one choice property often references another reflecting the confluent nature of the design quality properties as Alexander defines them in physical architecture. (Alexander 2002)
Stepwise Refinement (as the name implies) is an approach to elaboration that presumes a problem should be addressed in stages. The stages may represent degrees of detail or an expanding problem scope. (Birrell and Ould 1988) In either case quality evidence of stepwise refinement is demonstrated by the cogent and complete representation of a design element at whatever level of detail or scope is set at each stage. To achieve this representation the modeling paradigm must support abstraction that allows generalization of the scope of interest and then the elaboration of that scope from one stage to the next.

In the relational paradigm the choice of attributes along with their interdependencies forms entities depicting facts. Each relation depicts a cohesive, encapsulated and distinct segment of knowledge. Each instance of that knowledge depends on its distinguishable identity: tuple by tuple. The scope of knowledge included in any particular model is constructed by the aggregation of these distinct segments interwoven through their explicit relationships. A whole model is built up stepwise as the “subset of the universe” chosen for the model (its intension) is systematically surveyed, cataloged and defined in the collection of relations. Each relation’s integrity is achieved through its independent correctness separate and distinct except for those relations with which it maintains foreign key relationships. But the correctness of the whole proceeds from the stepwise assembly of the entire set of relations that together describe the reach of a model’s responsibilities.

Cohesion is a quality property reflecting a consistent responsibility distribution in a field of system components. (Zuse, 1997) Each relation serves a separate, cohesive role in the responsibility of representing domain knowledge. Relations reflect identity as they distinctly capture and represent concepts in the form of facts collected to represent cogent, clearly defined information. The tuples within relations similarly represent cogent, unambiguously defined instances of reality patterned after the attribute structure of their containing relation while by virtue of their entity integrity they remain distinct from any other tuple therein. The population of tuples in a relation reflects the ebb and flow of experience that the relation captures in the dynamics of the represented reality (the extension). The attribute structure of the relation as a template for each of its tuples ensures that the experience remains comparable and thus understandable regardless of the number of instances that experience produces. Functional dependency and its role in normalization assure that each relation represents an unambiguous and atomic division of knowledge in the modeling space. The result is a collection of distinct knowledge experiences bound together by a structure that both explains the significance of each instance and enables the analysis of that experience in terms of the whole reality that the relation captures.

Encapsulation is a design quality isolating and insulating instances of domain knowledge. In the relational paradigm the individual relation assumes the responsibility for capturing and defining the “reality,” the “facts,” the modeler chooses to instill in a model. The modeler’s intension is represented in the structure of facts that each of its instances must be able to remember. Each instance of the relation remembers by way of the data attribute value set in each tuple. An important part of the reality captured in each tuple is its individuality and the uniqueness of the information that it remembers in its data attribute values, its entity integrity. The truthfulness of individual tuples can thus be independently established as an encapsulated division of “reality.” (Scott, 2006) This individuality is determined solely by the values encapsulated therein dependent on no other information or relationships as characterized by Second Normal Form.

Extensibility is the property of design quality most important in pursuing systems with sustainability essential to cost of ownership economy. Extensibility juxtaposes the potential for new functionality with the effort required to achieve it. (van Vliet, 2008). Although each relation (down to the individual tuple) represents an independent depiction of reality in a relational model, more complex information is realized and extended through the relationships that associate relations. Associations permit the depiction of more elaborate descriptions of a model’s responsibilities. Associations depict correspondence, interdependence or even ownership of concepts between and among relations. These associations are employed through the relational operators that combine or collect facts resident in multiple relations and render them correlated, organized and/or extracted as a consistent but distinct representation of knowledge contained in the model.
Modularization along with cohesion expresses “divide and conquer” problem solving augmented by the flexibility of configuring and reconfiguring model elements. Modularization also supports scale permitting the composition of subsystems of varying scope that hold details in abeyance until they require focus. (Baldwin and Clark, 2000) Enlightened module partitioning exposes the solution structure envisioned by the modeler and publishes intentions for further extension by separation of concerns and isolation of accidents of implementation. (Brooks, 1987) By the nature of depicting model knowledge in a collection of individual relations that knowledge is subdivided and compartmentalized. The process of normalization assures that the intension depicted by individual relations and combinations of relations through their associations are not ambiguous, redundant or inconsistent. The compartmentalization of knowledge not only affords stakeholders a clearer view of relations individually, but also exposes the opportunities to safely recombine that knowledge through relational operations. This cohesion that distinguishes each relation’s role in the intension of the model also segregates the concerns that accomplish the model’s responsibilities and permits attention to be focused on relevant subsets within the overall model’s complexity.

Correctness in software engineering is often narrowly defined as computing the desired function. (Pollack, 1982) Thriving Systems Theory frames this property upon two outcomes: 1) validation, the clarity and fidelity of the represented understanding of system characteristics, and 2) verification, the completeness and effectiveness of model feature testing both individually and in composition.

Validation depends on the fidelity of the unfolding process; that through the stages of stepwise refinement the “essence” of system characteristics are brought forward maintaining their integrity. (Brooks, 1987) Modularization aids in cataloging and focusing on individual essential characteristics. Correctness is the only choice property that directly supports itself! Correctness must be a priority at each stage as shortcomings grow more and more expensive to rehabilitate as models evolve.

Verification depends on the effective testability of each choice to certify it as “consistent with stakeholder understanding.” Modularization enables the verification of individual choices or relations. Then relying on the correctness of individual relations verification can turn to the certification of relationships resulting from composition of function.

Entity integrity, referential integrity and normalization directly support a relational model’s fidelity to the modeler’s intension. Entity integrity assures that the uniqueness of each depiction of reality (extension) is enforced by the structure of the relation, intension, (the attribute set, their respective data attribute domains and the respective functional dependencies). The specification of that subset of attributes that will always contain a unique (combination of) value(s) defines the discriminating characteristics of that knowledge (the primary key) - the conformance to which is easily tested and thus protected. Referential integrity assures not only that data attribute values conform to the intension of their relation’s data attribute domain but, further to the modeled intension of associations between tuples including the ownership relationship between relations. Normalization extends the assurance of fidelity (model to the modeler’s intension) by assuring that the interrelationship among data attribute values not only supports entity integrity and referential integrity, but also inhibits the accidental loss of model knowledge (anomalies) through the action of relational operators.

Transparency is evident structure, revealing how things fit and work together. (Kaisler, 2005) The relational paradigm facilitates transparency in two obvious respects. Inspecting the relevant data attribute values is sufficient to assess every aspect of integrity whether entity integrity or referential integrity. These same continuously accessible values form the basis of all relationships among data attribute values or among relations. The consistency of each and every data attribute value can be certified. At any time before or after any and every relational database operation we can verify concurrence with the time independent definition of intension given by the data attribute set and their respective data attribute domains along with the designation of candidate and foreign keys. There are no implied or hidden definitions of association or dependence. Every aspect of tuple or relation fidelity is discerned through self-evident information. The result of any relational operator is determined solely by the data attribute values of the relations involved.
Composition of Function - As a fundamental tool for managing complexity humans regularly attempt to decompose problems, issues or tasks into parts that either in themselves are sufficiently simple to permit direct solution or can through recursion be subdivided successively until they become sufficiently simple. This is a defining aspect of modularization.

Composition of function as a property of design quality is realized in model features that facilitate the extension or retargeting of the model in the future. It is the capacity to combine simple features to build more complicated ones (Meyer, 1988).

Each relation in a relational model represents a fundamental aspect of intension in the modeler’s depiction of reality. Association and the use of relational operators affect that fundamental intension deriving an answer to any query we may invent based on that fundamental knowledge. The result of every relational operation is itself a relation. The modeler's ingenuity and discipline in forming queries carefully that yield results, relations, that are themselves consistent with the integrity constraints of the model creates the potential of an endless cascade of query result as input to another query and so on. This is the direct result of the mathematical formalism upon which the relation model is based – the predominating strength of the relational paradigm. The form in which these queries may be posed to a relational system is constrained only by the choice of mathematical representations (e.g. tuple calculus or domain calculus) or transformations (e.g. relational algebra or relational calculus) to the underlying relational definition.

Identity is at the root of recognition and is another property of design quality not usually defined in software engineering. In the physical world identity is literal based upon direct sensorimotor experience: by sight or touch and in some cases by sound or smell – a human experience of the "real" world. In the relational paradigm this human experience is applied directly by collecting those attributes that completely describe how any particular instance is unique – the combination of attributes that comprise the primary key. (Khoshafian and Copeland, 1986) The primary key serves to anchor the knowledge that surrounds it – those additional attributes that further describe the tuple which it uniquely determines – those attribute values that are functionally dependent upon the primary key. No tuple is permitted to exist in the relational universe (extension) unless it has a primary key – entity integrity. Ownership as it is manifest through foreign key associations is also anchored on the primary key of the owner tuple.

Scale’s effect on design quality is reflected in common idioms: “You can’t see the forest for the trees!” and “Let’s get a view from 10,000 feet.” They reflect the importance of context in recognition and decision-making. Scale captures the modeling imperative that all choices must be kept in perspective because it is not sufficient to consider a choice only in the microcosm of itself, as it must also participate in the connectedness of the whole. By achieving scale, a system designer provides differing granularities of comprehensibility to suit the requirements of a variety of observers (Waguespack, 2010).

In many cases the only familiarity that is needed in a relational model is the intension – the collection of relation definitions with their attribute sets defining their respective attribute domains and the associations among the relations. The knowledge structure and semantic relationships that may be mined through relational operators sufficiently defines any derivation of information representations that queries may be formulated to elicit. In terms of scale any relational model (intension or extension) may be expanded to incorporate additional knowledge. The modeler achieves this by grafting new knowledge onto existing relation structure through the addition and/or alignment of data attribute domains and associations.

User Friendliness is another property of design quality more often considered aesthetic. It is a combination of: ease of learning; high speed of user task performance; low user error rate; subjective user satisfaction; and, user retention over time (Shneiderman, 1992). Its impact may be easiest to consider in its absence. A modeling choice that is “unfriendly” to stakeholders is confusing, hard to comprehend, unwieldy, and perhaps worst of all, of indeterminate correctness. That which defies understanding cannot be determined to be correct. Satisfaction is cumulative. The sensitivity to the stakeholders’ conceptions of the essence of the system to be modeled is key to the stakeholders’ sense of comfort, familiarity, and expectation.

There is elegance in the succinctness and simplicity that arises from properly isolating domain knowledge in the respective relations. The use of user/client/customer familiar naming
of relations and attributes and the choice of the commonly used, domain based attribute values lends a comfort level to the representation of problem domain experience. The relational model also enables the derivation of contained knowledge at levels of granularity much higher than the individual tuple or relation. This is because relational operations on relations produce relations as their result. Information derived from a relational database can be presented as if it were simply retrieved from a single physical relation. This illusion is easily achieved in relational programming languages that support the definition and storage of queries that may then be referenced themselves as relations without the users’ notice (i.e. in ANSI SQL the “create view” syntax). The facility of such extensions to apply relational operations so discretely creates virtually unlimited opportunities and permits what might otherwise be a complex and daunting algorithm of derivation to be completely ignored by the users.

Patterns describe versatile templates to solve particular problems in many different situations (Gamma et al., 1995). Patterns is the property of design quality that channels change (unfolding). A pattern foreshadows where and how change will need to be accounted for. Patterns of the form popularized in (Coplein, 1995) document commonly encountered design questions offering carefully considered advice and cautions.

The most predominant pattern found in relational models is the regularity of structure that is embodied in the tuples that populates relations. This regularity assures that the same “questions” may be posed to each and every instance in a relation to elicit a consistently meaningful result. The tuples may be readily compared one to another and ordered that their factual content may be exhibited in a useful exposure of multiplicity. At the next level of structure we find the foreign key relationship where an association between relations is constructed by choosing attributes in the two relations that proceed from the same attribute domain. The pattern is further emphasized by the property of referential integrity. This pattern of connecting facts between and among relations permits the stepwise assemblage of higher and higher levels of derived information. The association enables the traversal of a network of concepts and facts that are both defined by and operationally enabled by the foreign key construct. The use of these patterns by the relational model designer provides the opportunity to lay out domain knowledge in a predictable and usable mapping.

Programmability in software engineering is often considered a feature rather than a property of design quality – the capability within hardware and software to change; to accept a new set of instructions that alter its behavior (Birrell and Ould, 1988). It is closely allied with extensibility and addresses the need for models to welcome the future. What largely separates information systems from other human-made mechanisms is the degree of adaptability that they offer to deal gracefully with change. Unlike most appliances that support a very narrow range of use (albeit with great reliability), contemporary information systems are expected to provide not only amplification of effort as in computation, but also amplification of opportunity in terms of different approaches to business or organizational questions. Contemporary information systems are expected to demonstrate that they can reliably accommodate change. As with extensibility, successful accommodation of change relies on an understanding of the fundamental options governing the structure and behavior within a particular domain.

What sets programmability apart from extensibility is a facility that permits altering the systems behavior without having to reconstruct choices – this versatility is not accidental but architectural.

Returning again to the use of relational operations to compose higher and higher levels of information we see individual relations as building blocks that may be arranged (assembled through relational operations) to yield any reasonable arrangement or derivation of information that the underlying relations may possess. This is possible because of the individual identity that each relation fosters in its tuples and because of the predictable reliability that proceeds from the consistency and safety of relational operations that is guaranteed in a set of normalized relations. The extent of information mining that may be attempted is limited almost solely by the programmers’ imagination.

Reliability is a property of design quality more often associated with implementation than design. It is the assurance that a product will perform its intended function for the required duration within a given environment (Pham, 2000).
There is an overarching simplicity that results from the fact that all of the properties of integrity are based upon data attribute values that may be readily inspected before or after any relational operation. Intension is expressed in modeled expressions of integrity constraints that are domain specific. The synchronization between the intension and extension of the model is easily tested because of this simple transparency. Reliability is assured if valid relational operations are applied consistent with model integrity constraints and thus will always yield consistent (“truthful”) information.

Reliability in design reflects an austerity that confines design elements to the essentials of the stakeholder’s intentions. When design or implementation decisions involve additional constructs due to technology or compatibility, these accidents of implementation must be clearly delineated so as not to imply that they are essence rather than accident. This clear distinction will protect future system evolution from mistaking accidental “baggage” as stakeholder intentions.

Elegance is perhaps the epitome of subjective quality assessment that clearly sets choice properties of design quality apart from traditional software engineering metrics. “Pleasing grace and style in appearance or manner,” that’s how the dictionary expresses the meaning of “elegance.” (Oxford English Dictionary)

“A designer knows he has achieved perfection not when there is nothing left to add, but when there is nothing left to take away.” (Raymond, 1996)

Models composed of choices that are consistent, clear, concise, coherent, cogent, and transparently correct exude elegance and nurture cooperation, constructive criticism and stakeholder community confidence. These are models that confess to their own shortcomings because their clarity obscures nothing, even omissions. These are models that satisfy stakeholders. They appear “intuitively obvious.”

Elegance is achieved largely through the relational model when relations are modeled with a minimum of extraneous or redundant information. Indeed eliminating redundancy is common mantra of relational modeling. The laying out of basic facts divided into distinct encapsulated containers of knowledge and the subsequent composition of higher levels of derived information effects a sense of economy of form and abundant opportunity for exploring and extracting the knowledge that a database so fashioned accommodates.

Elegance largely proceeds from the efficient and effective representation of essential system characteristics along with those features emerging out of design decisions, accidents of implementation, that are laid out with equal clarity for separate consideration. This is the field effect of the beneficial, integrated, mutual support of strong choices described in Thriving Systems Theory. (Waguespack, 2010c)

6. INTEGRATING THE DESIGN QUALITY LEARNING UNIT IN A RELATIONAL MODELING SYLLABUS

The design quality discussion provides a quality vocabulary for one-on-one consultations between teacher and student as each develops their relational models. In this one-on-one context each student’s specific design decisions may be discussed and evaluated in relationship to the design quality properties, an opportunity for individualized, reinforced learning and/or suggested improvements.

The deeper subtleties of design quality present a challenge for some students particularly in a compressed format. The “light doesn’t go on” right away for all students. However, the integration of the ontology and design quality property based vocabulary establishes a touchstone that returning students report helps them “to name” the “quality elements” they rediscover in succeeding coursework and professional practice.

In your own curricular situation the distribution of learning unit elements may span more than one course (some addressed in database programming, requirements engineering, or database design, etc.), be rearranged to suit your modeling tools, or be adjusted to your course sequencing with context-appropriate examples. Regardless, the learning unit components are flexible and robust enough to suit various specific program needs.

7. ACKNOWLEDGEMENTS

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8. REFERENCES


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Editor’s Note:

This paper was selected for inclusion in the journal as a ISECON 2012 Distinguished Paper. The acceptance rate is typically 7% for this category of paper based on blind reviews from six or more peers including three or more former best papers authors who did not submit a paper in 2012.
### Appendix A – Choice Properties (Waguespack 2010c)

<table>
<thead>
<tr>
<th>Choice Property</th>
<th>Modeling Action</th>
<th>Practical Action Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Stepwise Refinement</td>
<td>elaborate</td>
<td>develop or present (a theory, policy or system) in detail</td>
</tr>
<tr>
<td>2 Cohesion</td>
<td>factor</td>
<td>express as a product of factors</td>
</tr>
<tr>
<td>3 Encapsulation</td>
<td>encapsulate</td>
<td>enclose the essential features of something succinctly by a protective coating or membrane</td>
</tr>
<tr>
<td>4 Extensibility</td>
<td>extend</td>
<td>render something capable of expansion in scope, effect or meaning</td>
</tr>
<tr>
<td>5 Modularization</td>
<td>modularize</td>
<td>employing or involving a module or modules as the basis of design or construction</td>
</tr>
<tr>
<td>6 Correctness</td>
<td>align</td>
<td>put (things) into correct or appropriate relative positions</td>
</tr>
<tr>
<td>7 Transparency</td>
<td>expose</td>
<td>reveal the presence of (a quality or feeling)</td>
</tr>
<tr>
<td>8 Composition of Function</td>
<td>assemble</td>
<td>fit together the separate component parts of (a machine or other object)</td>
</tr>
<tr>
<td>9 Identity</td>
<td>identify</td>
<td>establish or indicate who or what (someone or something) is</td>
</tr>
<tr>
<td>10 Scale</td>
<td>focus</td>
<td>(of a person or their eyes) adapt to the prevailing level of light [abstraction] and become able to see clearly</td>
</tr>
<tr>
<td>11 User Friendliness</td>
<td>accommodate</td>
<td>fit in with the wishes or needs of</td>
</tr>
<tr>
<td>12 Patterns</td>
<td>pattern</td>
<td>give a regular or intelligible form to</td>
</tr>
<tr>
<td>13 Programmability</td>
<td>generalize</td>
<td>make or become more widely or generally applicable</td>
</tr>
<tr>
<td>14 Reliability</td>
<td>normalize</td>
<td>make something more normal, which typically means conforming to some regularity or rule</td>
</tr>
<tr>
<td>15 Elegance</td>
<td>coordinate</td>
<td>bring the different elements of (a complex activity or organization) into a relationship that is efficient or harmonious</td>
</tr>
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Appendix B - Relational Green Card (Waguespack 2010a)

The Relational "GREEN CARD" NOVEMBER 11, 2008

The Relational Paradigm

The Relational Ontology

This ontology is consistent with the practice in computer science and information science categorizing a domain of concepts (i.e., individuals, attributes, classes and relationships). This ontology of the relational paradigm of data modeling minimizes the vestiges of implementation languages and methodologies to expose the core nature of relational concepts.

1. Individuals
   The most concrete concept in the relational paradigm is the tuple.

1.1. Tuple
   A tuple corresponds 1-1 with a single concept of reality that it represents. A tuple collects the facts that identify it as a single concept and the facts most closely identified with it.

2. Attributes
   Attributes are those characteristics (facts) that describe a tuple. In the relational paradigm attributes define data characteristics - each of which has a static and dynamic form. A prescribed set of attributes defines what is called the structure of a tuple. From inception to extinction the structure of a tuple is immutable. The number of attributes in a tuple is called its degree.

2.1. Data Attribute
   Data attributes store information (data) in the tuple and implement the property of remembrance. Remembrance is manifest in each attribute dynamically as “what is remembered,” a particular data attribute value for each tuple derived from a data attribute domain that statically defines “what can be remembered,” the possible values of the attribute.

3. Classes
   The relational paradigm groups individuals into a collection called a relation. The relation corresponds directly with its mathematical antecedent where attribute values within each tuple reflect a correspondence with the coincidence of facts in the “real world,” a correspondence (attribute relationship) that is shared by every tuple in that relation.

3.1. Relation
   The relation concept combines both a definition of structure and the collection of tuple(s) based on that structure. A relation is defined as a fixed set of data attributes. Every tuple is an instance of a specific relation and shares the same static structure defined by that relation with every other tuple of that relation. The relation concept thereby fuses the existence of the tuples to that of their relation; tuples cannot exist independent of their defining relation. Tuples are said to be members of their relation. Tuples are added to or deleted from their relation. The order of attributes in a relation is insignificant except that the order is consistent for all tuples. A relation is also commonly called a table and each of its instances, a row. The collection of every data attribute value(s) for a particular data attribute in a table is called a column.

4. Relationships
   Relationships in the relational paradigm are based on the property of remembrance and the juxtaposition of data attribute values in one or more tuples in the same or across relations.

4.1. Behavioral Relationships
   The behavioral relationships are all based upon the data attribute value(s) and which values are permitted to coexist in and across tuples and relations.

4.1.1. Functional Dependency
   In a relation a data attribute is functionally dependent when its data attribute value is always the same in any tuple for a given value in a second data attribute. In other words, the value of the first data attribute is determined by the value of the second (called the determinant). Functional dependency expresses the informational integrity of relations.

4.1.1.1. Entity Integrity
   Entity integrity defines the two-fold quality of tuple uniqueness in a relation: a) every tuple in a relation is distinct in some data attribute

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value(s) from every other tuple in that relation or symmetrically, b) there is a designated subset of data attributes (column(s)) called the primary key such that the data attribute value(s) in that relation is distinct for all tuples and no values may be null (a value which is unknown and incomparable to any other value). There may be more than one subset of data attributes with the value characteristics of the primary key (each called a candidate key) but only one is designated as the primary key.

4.1.2. Association

An association is a relationship between tuples in the same or different relations. Tuples are intrinsically separable by way of entity integrity. At the same time, humans are compelled to categorize their experience of things in the physical world by superimposing groupings that collect tuples into sets. Tuples become members in a group based upon data attribute value(s). This property is called membership IN. This property also permits humans to identify a tuple that is not in a set (i.e. discrimination). (Membership IN, an association is distinct from membership OF a relation which is intrinsic by way of instance relationship.)

4.1.2.1. Relational Operations

Membership IN is realized through relational operations keying on relation structure and values. Each relational operation produces a real or virtual relation as its result. The selection operation retrieves tuple(s) based upon a selection predicate testing data attribute value(s) to determine whether each tuple is or is not in the set. Selection predicates are based on any boolean comparison including constant values or values referenced in data attribute value(s). The projection operation copies all the data attribute value(s) for a particular column(s).

Association between relations (or a relation and itself) is based upon relating (matching) data attribute values in tuples of one relation with those of another. The join operation pairs every combination of tuples from one relation with those of another relation and copies the data attribute values from the pairs where the pairing satisfies a selection predicate. This relational operation is called join because facts from two sources are joined in the result.

4.1.2.2. Join Compatibility

Join compatibility requires that the values involved in comparisons (i.e. selection predicates) whether constants or data attribute values derive from the same data attribute domain.

4.1.2.3. Referential Integrity

When relations are devised such that a tuple in one relation precedes the existence of (owns) tuple(s) in another, the data attribute(s) of the second required to join the relations is called a foreign key. Referential integrity asserts that any value found in the data value attribute(s) of a foreign key must appear in a tuple of the first relation as the value of a candidate key or itself be null.

4.1.3. Normalization

Relational model consistency depends on the semantic concurrence of the behavioral relationships and the objectives of the database modeler, the intension, (rather than the accident of a relation’s contents at any particular instant, its extension). The integrity properties defined above enable the database modeler to devise a structure and behavior of relations that avoid semantic discord called anomalies, the unintended loss or modification of information by relational operations. Relations designed to avoid certain kinds of anomalies are said to be normalized or in normal form. Normalization is the arrangement of data attributes and their relationships among relation structures to prevent particular anomalies.

4.1.3.1. First Normal Form

First Normal Form asserts that every data attribute value is atomic, indivisible in value or form and may not be operated upon except as a whole and single value.

4.1.3.2. Second Normal Form

Second Normal Form is first normal form and asserts that every data attribute value not in the primary key is fully functionally dependent upon the primary key. (“Fully” means applying to every data attribute of the primary key.)

4.1.3.3. Third Normal Form

Third Normal Form presupposes first and second normal forms and asserts that no data attribute outside the primary key is transitively dependent upon the primary key. (“Transitively” means an attribute(s) functionally dependent upon an attribute functionally dependent upon an attribute . . . functionally dependent on the primary key.)