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Using Variety Analyses to Improve Educational Sustainability and Liveability

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Abstract

This paper reports research into the application of Ashby's Law of Requisite Variety in tertiary education. The paper describes two approaches that apply variety analysis to convention curriculum design to address shortcomings both in relation to developing sustainable course designs and educational processes that improve the livability of education-related activities for academics and students.

This work builds on and continues the author's' (and colleague's) development of extensions to Ashby's Law of Requisite Variety that extend its role into the socio-cultural dimension of socio-technical systems.

The paper describes two new systems analysis techniques in the realm of sustainable curriculum design. It illustrates each through a brief real-world case study and derives from the analyses of two new generic extensions to Ashby's Law of Requisite Variety.

The paper concludes by outlining how changing curricula and course designs in the above manner, in addition to promoting sustainability, improve liveability in relation to the educational activities of academics and students.

Keywords: variety analysis, Ashby's law of requisite variety, sustainable curriculum design

Introduction

This paper describes research investigating the application of Ashby's Law of Requisite Variety (Conant & Ashby, 1970; Ashby, 1956) in relation the development of educational curricula using the variety analysis approach developed by the authors. Curriculum Design is ubiquitous across all aspects of education but is relatively naïve in its development of design methods and theories compared to many other design fields. The application of variety analysis in this curriculum design context builds on and extends similar research by the authors in the fields of digital ecosystems, software development, research management, information security, unionism and activism (see, for example, Love & Cooper, 2008; Love & Cooper, 2007a, 2007b, 2007c).

Paper Guidelines

The paper describes the application of variety analysis to curriculum design in the tertiary education sector to identify and overcome gaps in conventional curriculum planning and design processes. Two advantages of the use of variety analysis in relation to this conference is it provides a basis for designing sustainable education programs that provide improved liveability factors for students, educators and education managers.

The variety analysis approach developed by the authors and described below in terms of curriculum design extends the application of Ashby's LoRV into complex socio-technical realms. The authors' variety analysis approach differs substantially from traditional use of Ashby's LoRV which typically is seen as applicable only to hard quantitative subjects of study such as information and communication systems or as a relatively token foundation for other cybernetic theory developments such as Beer's Viable System Model (refs).

Curriculum design and education programs are complex socio-technical systems. The application of variety analysis in these contexts reveals important issues not easily seen by conventional modes of curriculum analysis and design that are otherwise easily overlooked, ignored and not addressed. It also, through the mode of analysis, reveals potential solutions and provides a means to identify which solutions are more optimal in the solution space.

This paper uses two short case studies to demonstrate the value of variety analysis and the authors' extension of Ashby's LoRV into the realm of complex socio-technical systems in the tertiary education sector. The first case study is a postgraduate collection of programs in Humanities at Curtin University of Technology in Western Australia. The second is a general variety-based analysis of variety-based issues in Design as a subject. This is particularly in relation to PhD and research Masters programs in design where the variety analysis approach identifies that Design as a discipline has a different amount, distribution, type and dynamic of variety compared to other established disciplines. The research indicates that because of this, the distribution of control variety in Design, which emerges in theses, research analyses, and the sentence structures in documents describing design-related research, must be different in order to address these different distribution dynamics of system-generated variety.

From both case studies emerge of two further extensions to Ashby's Law of Requisite Variety (LoRV) that add to the six extensions to Ashby's LoRV previously reported by the authors (Love & Cooper, 2008; Love & Cooper, 2007a, 2007b, 2007c).

The paper consists of five sections. The following section briefly outlines the use of Ashby's LoRV in relation to complex socio-technical systems such as curriculum design. The third section describes the first of the case studies: the design of a Masters' program. Section four describes the second case study: the significant differences in variety distribution and type between research that is focused on design activity and other research. Section five, the concluding section, describes the two new extensions to Ashby's LoRV that emerged from these studies.

Variety concepts in education program analysis and design

The cybernetic work of William Ross Ashby has widely influenced researchers involved in systemic analysis and system design to the present through his contributions to systems thinking, cybernetics, control theory and operations research, particularly through his law of requisite variety. Ashby's Law of Requisite Variety is perhaps the only 'Law' that is held true across the diverse disciplines of informatics, system design cybernetics, communications systems and information systems (Heylighen & Joslyn, 2001). This law is stated in short form in many different ways, e.g., 'only variety can destroy variety' (Ashby, 1956, p. 207) and 'every good regulator of a system must be a model of that system'(Conant & Ashby, 1970). More fully, Ashby's Law states that to control any system, the amount of variety (i.e. the number of possible states) of the controlling process has to be at least the amount of variety (number of states) that the system is capable of exhibiting.

Variety in a system comprises anything about that system that can be different or changed. Systems attributes that can have variety include information; organisational structure; system processes; system activities; inputs; outputs; functions; participants; control mechanisms; ownership and control; opinions, judgments and emotions. In complex socio-technical systems, control and system variety elements are distributed across the system and across constituencies. The distribution of variety and the control of variety may change over time.

Ashby's LoRV provides a significant reference point for system designers to understand whether the design of a complex system is likely to be manageable, stable and viable. The origin of Ashby's LoRV is in communication theory and cybernetics. To date, Ashby's LoRV has been primarily applied to analysis of systems that can be represented in information terms. Where the LoRV has been applied to human systems, the focus in research to this point has remained on representing the human systems informatically with its rationalist limitations that preclude the inclusion of subjective considerations.

As would be expected, a variety-based approach to understanding curriculum design is grounded in studying the types and distribution of variety in that program, course or unit. From this perspective, educational programs, courses and units can be viewed as being totally and completely defined in variety terms. This provides a wholly parallel and alternative approach to conventional curriculum analysis and design approaches that tend to have a primary focus on course content and teaching and learning methods. In the variety approach described here, 'course content', 'teaching and learning styles', assessment processes' etc are secondary to studying the variety dynamics of which they are part, as part of the different types of variety found in a program, course or unit. In looking at things via this variety lens, the concept of 'variety' refers to ***anything*** that can vary. Two structurally different types of variety are important: 'system generated varieties' and 'control varieties'. Any program, course or unit exists as a system that generates variety via, for example, the students it accepts, the content and the teaching and learning. The course is shaped by the control varieties of, for example, the mechanisms and choices of exactly which students are accepted, exactly which content is taught, which teaching modalities are used, how the course is assessed, and which resources are provided. As a whole system, any program, course or unit is defined exactly by its distribution in time, location and type of its system generated varieties and control varieties.

Education programs are characterized by high and variable levels of variety distributed across multiple system variety-generating sources and multiple variety-controlling mechanisms. For example, a student cohort will, as a given, bring in system variety in terms of the student numbers, gender mix, levels of skill and knowledge, interests, learning styles, ages, gender etc. In terms of the course content and delivery, in potentia, any individual unit, course or program could be focused on just about anything, at any time, by anyone, at any standard. In addition, course variety is also shaped by teaching and learning approaches and the resources made available. In addition, there are system generating varieties and control varieties that are associated with the extended contexts within which education is located such as those associated with the teaching institution, national and local education policies, international, national and local cultural factors related to, for example economic and social development.

In essence, in curriculum design situations there are four main types of system generated variety related to:

- Student characteristics
- Course content characteristics
- Teaching and learning characteristics
- Resource characteristics

Constraining this situation, controlling and bounding mechanisms are put in place such that their own variety, control variety, is used to stabilize the potential anything goes variety related to the students, course content, teaching and resource related varieties. These include:

- What will be taught
- When
- In what ways
- Using specific resources
- Assessed in particular ways
- Defined student cohort

In order to be able to critique the design of any education course, unit or program, systems boundaries need to be usually established. The system boundaries to identify improvements to individuals' learning of a particular topic are quite different from those used for critiquing the design of a new faculty organization structure. The action of defining the systems boundaries is essential because they provide the basis for identifying the main sources, types and scale of system generated variety and the potential control mechanisms that define the system ontologically in terms of 'what it is', 'what it does', 'how it functions' and 'how it is controlled'.

At this point, system generating variety and control variety in a bounded system can be relativistically assessed. In the case of curriculum design, this is usually via analyzing practical experience provided by professional educational experts. For example, student services, demonstrators, lecturers and tutors can typically be expected to easily identify the significant varieties associated with the student cohort. Educational research data from national and local sources also contributes to understanding variety related to a student cohort. Similarly, curriculum designers identify the opportunities for generation of control variety via means such as course structures, teaching modalities, course content, course presentation, assessment modalities etc. that have the potential for defining a program, course, unit by controlling expected system varieties.

The challenge is in choosing and matching ways of applying control variety that offer maximally beneficial results as measured by the chosen outcome metrics such as: graduate attributes, retention, student satisfaction, financial viability, benchmarked cohort mark profiles, research training potential. This is a role in which variety analysis and extensions to Ashby's LoRV offer potential to identify and to address significant gaps in traditional curriculum design approaches.

Case Study 1 Integrated Masters Program in Design and Art at Curtin University of Technology

The background to this situation is the ongoing transition in universities to restructure to minimize costs and align subject areas and what is taught with students' interests of the moment. In essence, these are strategic changes that any commercial organization makes in restructuring to become more profitable and increase market share. The process is at heart a move towards ***sustainable*** course design.

In this particular case, the organizational situation comprised the combining of two business units, a Department of Design and a Department of Art, into a single school. At this point, there exists separately in each school an honours program, a taught coursework Masters course, a research-based Masters course and a PhD program. In addition, it is possible for students to leave the taught Masters programs partway through and be awarded a Postgraduate Certificates or, at a slightly higher standard, a Postgraduate Diploma. All of these programs are different in each school and there are twelve programs in all. The fundamental difference between the programs is that the Department of Design programs align predominately with conventional modes of scholarship, with a commercial bent somewhat similar to Engineering programs, whereas, culturally, the Department of Art programs are dominated by an interest in the creative rather than commercial output of their students.

The changes that were proposed by committees in the Faculty were intended to make these postgraduate Design and Art awards more profitable and more attractive to students, and also align them with the European-based Bologna Accord and process (see, (DEST, 2006) and http://www.ond.vlaanderen.be/hogeronderwijs/bologna/). An important issue was that the Bologna Accord requires a student to be able to transition between and across courses in a variety of ways.

Rending the situation more complex in this particular context are two requirements of the Department of Art:

- That practical hand skills have to be assessed in a postgraduate manner as equivalent to research skills or other post graduate attributes
- that there needed to be a layered structure of skill building to provide prerequisites between lower and upper courses in order to provide an ongoing pathway of craft skill building in parallel with or as an alternative to academic skills.

This complex curriculum design case offered the opportunity to explore this use of Ashby's LoRV to investigate optimal ways of designing the Masters program structure as it is the Masters program that provides the basis and hinge point around which the whole of the articulation of the post-degree programs (including Honours) must be arranged. The Honours, Masters by Research and PhD programs being substantially defined at Faculty and university levels rather than at Department or School level.

From a combination of committees within the newly minted School of Design and Art and the overarching Faculty of Humanities, it was proposed there should be two different honours programs: one aimed at research and the other aimed at the development of craft-based creative art skills. The proposal suggested that Masters programs should comprise two different streams of taught Masters by Coursework: one academic Masters by Coursework stream and one Professional Masters by Coursework stream. Above these would be arraigned a Masters by Research, again in two forms: a conventional Masters by Research and a 'Masters by Research' that has 'creative art practices' as a substitute for research. Above these is a PhD program again divided into conventional PhDs and PhDs with a creative arts outcome and exegesis (previously known as the Doctor of Creative Arts). In all, this continues the model of eight programs, or twelve programs if Postgraduate Certificates and Diplomas are included. Potentially each program would be taught differently in the Departments of Design and Art. This results in 16 or 24 different programs in all. In terms of variety, the approach is one of providing requisite control variety via the number of different courses.

Lurking like an elephant in the room but presently ignored and 'prohibited from discussion' is that both the Department of Art and the Department of Design each comprise multiple very different subject specializations. For example, in the Dept of Art, Painting is very different from Ceramics. In the Department of Design, subject areas such as Advertising, Furniture Design, Typography and Design of Organizations are very different. Tacitly hidden but lurking in the discussions is the need to enable these specializations. This implies that as the new course structure is agreed at a university level, there will emerge ongoing pressure at local level for multiple course variants to address the needs of the many different subject specializations in Design and Art in these Honours and Masters programs.

Viewing this messy curriculum design situation from the perspective of variety analysis shows the overall system-generated variety comprises varieties from different sources. Varieties associated with students include:

- Age
- Gender
- Number of students
- Skills
- Prior education
- Competence
- Intelligence
- Interests
- Learning attributes/types
- Financial status
- Country of origin
- Legal contexts (many students use education provisions of immigration to obtain residency in Australia)

The academic environment brings system generated varieties, such as:

- Numbers of staff
- Staff skills
- Staff Interests
- Staff subject areas
- Staff research areas
- Teaching skills

These varieties must be at least matched by a requisite amount of control variety. Possible control variety distribution can also be mapped onto dimensions such as:

- Number of courses
- Types of courses
- Learning/teaching styles catered for
- Course content
- Curriculum variability
- Education processes
- Ability to address different learning situations (e.g. negotiated learning, auto-didactic learning, recognition n of prior learning, authentic learning, professional experience etc)

The outcome chosen by the committee responsible for addressing the above situation between Design and Art chose a conventional curriculum design approach to respond to the variety generated by students and staff as described in the early part of this case study by increasing the number of courses to provide the requisite variety.

The above strategy, however, is only one way that the requisite control varieties can be generated. There are many ways to satisfy Ashby's LoRV, each with different levels of cost and associated benefits. Fulfilling the LoRV by increasing the number of courses is a simple but messy and expensive approach. What it does have in its favour from an academics' perspective, however, is it maximizes the need for teaching staff and results in lower class numbers with support for staff subject specialization. In addition, it is implicitly assumed that course standards will be lowered so that generic courses can be used to cover the variety of subject interests of students.

Increasing the number of courses whilst at the same time minimizing the variety in any one course effectively locks each course to a particular specific mix of content, learning style, learning experience, targeting a specific group of students with particular characteristics.

There are multiple weaknesses of this approach. The most obvious are:

- It is expensive (multiple courses, lecturers, rooms, etc)
- It fails to produce the required results (cannot adequately match variety at an individual level)
- It is likely to sabotaged by specialists in departments re-jigging their courses to match with the need for specialist education

Variety Analysis reveals several alternative approaches that have less weaknesses and problems than the above. One alternative is to have a very small number of courses, for example, only one honours, one Masters and one PhD course with increased flexibility within each course to provide the control variety to match the system-generated variety. That is, control variety would be within each course rather than via the number of multiple courses. Many education modes align with this solution in an effective and economic and attractive manner. The most obvious in the Design and Art context is to use authentic problem-based education where students' primary learning comes via addressing and resolving a real-world problem of interest to them as individuals, i.e. each student addresses a different problem.

Variety analysis reveals multiple educational strategies by which control variety can be designed to match system generated variety. Each has different advantages and costs and thus variety analysis can extend curriculum design approaches to identify course and curriculum alternatives that have advantages and costs that best match with the strategic management direction of an educational institution.

The above case study analysis demonstrates how using variety-based analysis opens up the opportunity for new directions in identifying solutions and strategies for improving curriculum design of programs, courses and units. It does this by revealing and addressing omissions of the techniques of conventional curriculum design.

The case study also leads to a curriculum design guideline that is the authors' seventh extension of Ashby's Law of Requisite Variety, i.e.

Seventh extension to Ashby's Law of Requisite Variety

For complex educational program systems that have multiple elements of awards that are linked hierarchically and crosswise between awards and have socio-technical system varieties involving multiple constituencies, knowledge areas, skills, modes of teaching and learning and constituent orientations

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The solution space is bounded by the distribution of control variety provided:

- *By the number and types of courses*
- *The variety within each course*
- *The resources available to courses*
- *The assessment modalities*

AND

The relative benefit-cost of each solution can be mapped, and assessed by a 'hill climbing' method, in a solution space whose dimensions can be represented by an array of size = a *x* b *x* c *. Where* a *is the number of system generated varieties,* b *is the number of control varieties and* c *is the number of benefits and costs identified by stakeholders. In the case of Requisite Variety being just satisfied, the solution space dimensions =* 2ac*.*

Case Study 2: Conceptual Complexity of a Subject Area

Different subject areas of scholarship have different distributions and levels of variety in their concepts and terminology. Some areas such as Physics have a low variety of concepts for each term. Other subject areas are quite complex conceptually and terminologically, i.e. they have multiple conceptual meanings for each term: a high conceptual variety. For education programs this conceptual variety of terms is part of the system-generated variety of a subject area and the educational program, courses or units within it. Addressing the implications of this issue is important for the *sustainability* of education programs.

Two curriculum design questions that immediately follow from this understanding are:

- What are the implications of areas of study having different levels of conceptual variety of terms compared to other courses?
- How can one use variety analysis and an understanding of Ashby's LoRV to identify the best design strategies for implementing control variety to achieve sustainable satisfactory educational outcomes, reducing costs, and reducing stress on academic staff (i.e. improving *liveability*).

This case study looks at a subject area, Design, with a very high level of conceptual variety in its terms. An idea of the very high level of conceptual variety in Design can be gained by looking at the terms 'design' and 'emotion'. The following makes the situation more concrete by focusing on the specific area of design of emotional web-based screen interfaces.

Conceptual variety of the terms 'design' and 'emotion'

The term 'design' applies simultaneously in many ways to uniquely different entities in a single element of research, document or analysis. For example, the term design might refer at different points to:

- The actualized 'design' of the interface as is used by the user
- The design as the specification for creating the interface as actualized
- The conceptual design as experienced by the user
- The cognitive model of that conceptual design as emulated in the user's head
- The design of the software code that results in the screen
- The design of the graphic appearance of the screen
- The design of the underlying logic model that drives the functioning of the screen
- The design of the different logic model that defines the database structure and related coding
- The designs are processed by the different aspects and levels of computer systems
- The service design, i.e. what the screen is intended to do expressed in service process terms
- The design(s) of all of the above 'on paper' as distinct from their 'conceptual' selves.
- The design (as above) as they exist in the different designer's heads
- The partial, speculative or potential candidate designs, many of which will not result in outcomes
- The initial concept design of the brief

In any academic discussion using the term design, several of the above different conceptual meanings of the term are likely to be included in the same sentence, paragraph or section. To make unambiguous sense in the discourse, this requires discussion of research, and analysis relating to design to be constructed with all necessary differentiating clauses and in turn carefully parsed by the reader or student.

A similar situation is found relating to the word 'emotion' in the design of interfaces. There is an approximately one to one correspondence with the above list of structurally and conceptually different takes on the word 'design' plus there are some aspects in which the physical elements of the computer providing an interface/screen can also be seen as processing emotion related information. This is particularly significant in situations in which artificial intelligence underpins the behaviours of emotionally responsive interfaces. The effect is an increase by an order or more over and above the variety of use of 'design' in the variety of the term 'emotion' in discussions about research and analysis of 'emotion' in design situations.

The variety issue blows out in design research in analyses that involve two or more high variety conceptual terms such as 'design' and 'emotion' and in which multiple different versions of each are used in each sentence. The level of system generated variety can be such that it needs to be addressed using sources of control variety over and beyond the usual control variety management conventions of dialectic discourse. In one particular analysis, the author found it necessary to add three alphameric suffixes to the term emotion to differentiate the differently conceptualized uses of the term (e.g. "emotion_{1A3}") (Love, 2001). This was to ensure that the number of definition and qualifying clauses in sentences could be reduced to the level at which the sentences were short enough to be readable

From an educational perspective, this points to several practical issues and problems. Not only are sentences more complex, but they are also longer and more difficult to parse. This means that the thinking of the students in this realm is rendered much harder than for subjects with less conceptual variety per term. This is due to the additional overheads of differentiating in design texts between many very similar concepts using identical terms that might appear in exactly the same places in similar sentences but have radically different meanings.

In terms of developing and applying control variety to such as subject areas in which system generated variety relating to terms is unusually high (remember that in most subject areas, terms have only a ***single*** definition), there are a few options: some in current use and some better than others.

One option is to tightly structure the conceptual language similar to the single term/single concept/single definition approach used in other disciplines. This presents many problems in multiple sub-field subjects such as Design; the most obvious of which is that it does not reduce the intrinsic complexity of design research situations that is echoed by the high variety in the use of terms such as 'design' and 'emotion'.

Another option, and one that makes sense in several ways, is to reduce the **scope** of individual content elements of education and research in Design. Any review of the design research literature indicates that a weakness of most research reports and analyses is covering too much problem territory in too little detail. This is to some extent to be expected in view of the relative underdeveloped nature of the Design research discipline. It presents, however, problems because most individual issues are very highly cross linked across the whole multi-disciplinary

Design arena that any researcher or student is likely to be engaged. To focus on (say) 'designers' thinking' and not look at all the issues relating to 'users' interactions with designs' provides students little opportunity to perceive cross links between important issues such as how a designer's conceptualization of an issue can be modified by them observing users: a central component of many design methods

A strategy used often and disastrously in the design research field is to ignore the high level of system generated conceptual variety and to somehow 'muddle through' without addressing it. It is common for academic staff and many researchers to have not realized how much variety/complexity is involved. This problem is strongly represented in the design research and practice literature and is a factor that has delayed the development of the Design research field. From experience, problems of this ignoring of complexity are very visible in examining theses, research reports and papers written by design students in which the issues of conceptual variety of terms have been tacitly or explicitly ignored.

These variety analyses suggest that another potentially successful education strategy to control system generated variety of terminology is to adjust the size of study to encompass a scale of the issues being addressed. In most cases this means larger units of study and less breadth of material per unit. That is, to reduce the content density to provide the time and other resources to satisfactorily address the conceptual complexity

Another potential education strategy is to address the problem naturalistically via authentic learning. In this latter case, students are presented with a real-world problem instead of taught content. By addressing a real-world problem of design production and reporting their rationale and reasoning, students automatically learn to traverse the different layers of meaning of concepts and address the conceptual variety in a way that matches their learning styles and abilities.

In choosing which educational strategy has the most benefits and hence is more *sustainable* and offers best *liveability* for stakeholders, the variety-based approach offers ways of improving courses over and above the techniques of conventional curriculum design. In particular, this case study leads to a curriculum design guideline that is the authors' eighth extension of Ashby's Law of Requisite Variety.

Eighth extension of Ashby's Law of Requisite Variety

In complex socio-cultural/technical systems of knowledge, professional practice, analysis and teaching and learning in which the system generated variety of meaning of individual terms and concepts is high, multiple meanings occur in the same discourse and there is a dynamic overlapping distribution of multiple meanings of the same variety of terms and concepts across related sub-themes.

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Paper Guidelines

The generation of requisite control variety in discourse and analysis related to teaching and research requires necessary and sufficient use of:

- *Differentiation of specific individual meanings of these terms and concepts via careful and large-scale use of, i.e. linguistic techniques such as adjectival and adverbial phrases, suffixes and prefixes and other differentiating markers.*
- *Sentences with high variety (long and complex)*
- *Reduction in size of topics and projects compared to other subject areas (achievement of requisite variety via attenuation of system generated variety). In teaching*
- *Increase in size and scope of teaching and learning units compared to other subject areas (increase in resources available to accommodate increased system and control varieties)*

Conclusions

This paper has reported research investigating the application of variety analyses and extensions to Ashby's Law of Requisite Variety developed by the authors to the context of curriculum design in universities. It suggests these approaches offer benefits in making education courses more *sustainable* and more *liveable* for those involved.

The paper has illustrated the application in general of the authors' development of variety analyses and indicated some of the potential benefits for curriculum design. The paper described two case studies of variety-based analyses of curriculum design in postgraduate environments: one of an integration of postgraduate programs in Design and Art, the other addressing the issues when subject areas have high conceptual variety in its terminology. These case studies were used to illustrate aspects of variety analyses to provide significant and in some cases essential insights into important curriculum design considerations not readily visible via conventional curriculum design approaches. The case studies indicate how the authors' variety analysis approach to not only suggests solutions but also can be used to identify solutions in more optimal areas of solution space.

In addition, from the case studies were identified two extensions to Ashby's Law of Requisite Variety. These are published as extensions 7 and 8 in the authors' ongoing exploration of the application of Ashby's Law of Requisite Variety to socio-technical situations.

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