On the Design of Systems-Oriented University Curricula

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Abstract

This paper proposes a tool called the Systems Education Matrix (SEM) for use in informing the work of developers of systems-oriented curricula at colleges and universities around the world. The SEM was developed by Team 1 at the 2008 IFSR Fuschl Conversation held at Fuschl am See in Austria. In order to manage the complex problems we are dealing with today, systems thinking is essential. It is clear that systems education should be acknowledged as an important "scientific method" that can help today's society to deal with the complexities of contemporary issues. To serve this role effectively, systems education needs to be focused towards the various needs that exist. The members of Team 1 have focused on the nature of systems education that will be required to not only train systems specialists, but to make systems thinking and analysis an integral part of discipline focused research and management.

Key Words: systems thinking, systems education matrix (SEM), dialogue

1. Introduction

This paper proposes a tool called the Systems Education Matrix (SEM) for use in informing the work of developers of systems-oriented curricula at colleges and universities around the world. The SEM was developed by Team 1 at the 2008 IFSR (International Federation for Systems Research) Fuschl Conversation held at Fuschl-am-See in Austria. The paper is loosely divided into three sections, covering respectively: A synopsis of the group process (Section 2); An overview of the current state of systems education followed during the development of the SEM (Section 3); and an explanation of the SEM itself (Section 4).

1.1. Systems Thinking in Context

In most educational, industrial, scientific and social contexts, in order to understand something better (e.g., an ecological system, an organization, a policy), we break it into parts and then study the parts separately (Ackoff et al., 2006). In this way, interdependencies and interactions between the constituent parts are overlooked, which are the very causes of complexity and dynamic behavior in systems.

The wide range of disciplines involved in addressing complex contemporary issues (e.g., climate change, sustainability of businesses) require the integration of diverse ranges of knowledge and skills. The ability to explore the complexity of interactions within the 'hard' system (the biophysical components) and within the 'soft' system (the interactions between the biophysical components, technology and people) requires a shift away from single disciplinary projects toward multi-disciplinary and inter-disciplinary research, and approaches.

To accomplish this, new ways of thinking are essential to manage the complex problems we are dealing with today. Systems thinking offers a way or 'method' with which to construct and explore inter-relationships at a variety of system levels (Bosch et al., 2007).

It is clear that systems education should be acknowledged as being in direct support of a science-based approach to helping today's society to deal with the complexities of contemporary issues. To serve this role effectively, systems education needs to be focused towards the various needs that exist. There is a need for systems specialists and theoreticians who can develop concepts, theory and tools. There is an even greater need for educating a wider spectrum of people in how to use these concepts and tools in solving complex problems. For example, statistical analysis is used as standard practice and is an integral part of all disciplines of science. Systems thinking, in contrast, is not (Bosch et al., 2007). In the same way that researchers do not all have to be statisticians, they also do not all need to be systems specialists.

This premise was the basis for Team 1's approach at the 2008 Fuschl Conversation. The members of Team 1 have focused on the nature of systems education that will be required to not only train systems specialists, but to make systems thinking and analysis an integral part of discipline focused research and management.

2. Overview of the Practice of Dialogue at 2008 Fuschl Conversation

The 2008 Fuschl Conversation incorporated the practice of dialogue as the intended means of communication and research within each research team. The word "dialogue" comes from the Greek word *dialogos*, meaning, “through the meaning of the word” (Martin, 2002). In modern usage, the word is often used with a meaning roughly equivalent to that of "conversation." Dialogue is a sub-set of conversation and can be contrasted with other types of conversation, such as discussion and dialectic. Discussion and dialectic involve the advocacy of one’s own opinion with the hope of convincing another person of a particular way of thinking. By contrast, the purpose of dialogue is to build true community among participants (Jenlink and Carr, 1996). “Dialogue is a unique form of conversation with potential to improve collective inquiry processes, to produce coordinated action among collectives, and to bring about genuine social change” (Isaacs, 1996, p.20).

Dialogue, in the sense that it is used here, is “not a new tool for addressing specific issues or problems. Rather, it is a means to help people to think together” (Banathy, 1996, p.218). It fills an urgent need in modern times and can serve as an important tool for the current global *problematique*. In its recent report on global sustainability, the United Nations recognizes “the importance of building human solidarity [and] the promotion of dialogue and cooperation among the world’s civilizations and peoples, irrespective of race, disabilities, religion, language, culture, or tradition” (United Nations, 2002, p.3).

2.1. Background and Stated Goals of the Fuschl Systems Education Team

In January of 2008, the members of Team 1 were asked to explore the "basic concept of systems sciences," and the Conference primer asked them to consider the following triggering questions:
(A) What concepts must a person know in order to call him/herself a ‘systems scientist?’
(B) Can we establish an ontology of systems concepts using Charles Francois' encyclopedia? (Francois, 2004)
(C) Can we define a systems science body of knowledge?
(D) What are existing / desirable University programs and courses – how much are they covering, compatible with (A) and (C)?
(E) Given the fuzzy borders of systems Sciences would it be helpful to separate the field into LARGE subfields, similarly to e.g. informatics (practical, applied, theoretical).
(F) Given that in Fuschl we cannot fully solve these questions, what is an appropriate road-map to achieve it, what should be the collaborators and what is the time frame?” (*IFSR Newsletter*, December, 2007)

Based upon these, the theme of Team 1's dialogue evolved as described below.

2.2. Process Overview of the Fuschl Systems Education Team

The semi-structured dialogue process which Team 1 followed during the development of the SEM over a four-day period may yield some useful insights into the origins, nature and purpose of the SEM itself. Therefore, a brief overview of the group process that Team 1 followed is covered below.

In terms of group process, Team 1 went through a fairly normal evolution in terms of group dynamics in a dialogue situation, oscillating between times of relative harmony and relative chaos. Through a strong spirit of determination and the effective use of experimenting with different dialogue tactics at points when the evolution of the process seemed to get stuck, Team 1 was able to produce an outcome that was satisfying to most or all members. Here are a few highlights of the process:

2.2.1. Phase I: Engaging Each Other (Day 1)

Team 1 took a pragmatic, structured approach to the dialogue experience. During the first session, two of the group members who were experienced with a particular type dialogue process explained their views of the concepts of generative and strategic dialogue to the rest of the group. The group then took turns explaining their input papers in their own words. This led into a generative dialogue session whereby the group explored the question of "What is quality education?" The generative dialogue session allowed the group's member to surface their own assumptions and values about what "quality education" meant to them.

2.2.2. Phase II: Two Key Insights (Day 1)

The group then shifted gears into a mode of strategic dialogue. This transition took place as the group began to formulate its collective goals for the Fuschl dialogue event. The agreement was to create, within the span of the 4-day Fuschl dialogue event, an output paper that would serve as an attempt to collectively respond to the pre-conference triggering questions. During this phase of strategic dialogue, two key insights began to emerge: 1. There is a need to develop and categorize multiple systems education curricula in order to serve different students who have varying needs and goals; 2. It would be useful to identify the range of systems concepts (e.g., autopoiesis, feedback, homeostasis, etc.) such that each can be properly matched with each curriculum category.

2.2.3. Phase III: Making a First Attempt at Classification (Day 2)

After the two key insights emerged, the group soon developed a diagram in order to categorize the types of systems curricula required. The diagram contained two primary categories: "integrated" and "systems knowledge per se." The "integrated" category was further divided into two sub-categories: "to aid in work readiness" and "learning in the context of a given discipline." Meanwhile, the "systems knowledge per se" category was further divided into the sub-categories of "for basic understanding" and "for mastery." A fifth sub-category was also added to the diagram: a pre-university "intro to systems" course. This 5-sub-category diagram came to be known unofficially as the systems Education Blob.

2.2.4. Phase IV: Hitting a Wall and Changing Tactics (Day 3)

Once the systems Education Blob was conceived, the group set as its next goal to generate and then classify examples of commonly-recognized systems concepts that could be fit into each of the systems education categories created in the Blob. The list was meant to be a "starter list" that could be augmented at any time in the future by individual practitioners in order to create a more expansive list of systems concepts. The group generated 76 systems concepts at that point. At this point in the process, the group hit a figurative wall in terms of its progress.

2.2. 5. Phase V: Breakthrough (Day 4)

Team 1 achieved a breakthrough of sorts when it gave up on the idea of trying to find a way to rigorously classify systems concepts as previously desired. For the remainder of the dialogue event, the group shifted its focus, eventually producing a derivative of the Blob: the Systems Education Matrix. The matrix organized the systems education landscape into two main dimensions: the *depth and type of* *systems knowledge required*, and whether systems concepts are taught *per se* or rather through application within one or more specific disciplines.

3. The Current State of Systems Education at the University Level

3.1. Challenges and Opportunities

Systems education today faces a number of barriers (constraints and challenges) if it is to become a more prominent feature of global institutions of higher education. At the same time, the wider implementation of systems-oriented curricula in higher education affords substantial opportunities for students, professors, industry, local communities, and the globe.

3.1.1. Challenge: Complying with the Needs of Industry

The revolution that is taking place regarding the integration of systems concepts into discipline specific courses is not only driven by the need to train systems scientists who can deal with the complex issues, also by the need to instill systems thinking attributes in our graduates.

Industry requires graduates that will not only have in-depth knowledge in the field(s) studied, but who also can display effective communication skills, independence and creativity, critical judgment and ethical and social understanding. Of particular importance is the ability to develop analytical frameworks that can be used to critically analyze complex situations, solve problems and make decisions for system improvements. Universities should play an active role in enhancing the educational experience of students by focusing on high quality programs and developing a high degree of work-readiness of graduates through incorporating courses that will enhance personal and professional skills. Systems approaches are important mechanisms to help achieve the attributes that industry wants from future graduates - for example, the ability to contextualize (systems thinking skills), to identify issues, develop strategies, managing projects (unraveling complexity and problem solving models), convey the message (communication), the ability to build resilience and being adaptable (dealing with change and complexity), and to build effective networks and work in teams (personal and collaborative skills).

These issues create a significant pedagogical challenge in that current university education tends to be focused on discipline specific teaching which has no room for a wider systems approach. Didactic autonomous discipline based courses fail to foster a social networking culture that has been proven to enhance the process of deep learning, nor do they promote interactions with other students in other disciplines. To address this problem we need innovative curriculum designs and learning environments that address academic paradigms as well as industry requirements.

3.1.2. Challenge: Defining the Proper Boundaries and Recipients of Systems Education

System thinking may be taught in any university education program. However, systems education must take into account the different goals of university courses and programs. Most of the students will later work in fields where they need to apply what they have learned. They must be educated with knowledge they can use immediately, including with a basic thinking framework and perhaps several relevant system approaches or concepts. A few students, however, will become researchers themselves and hence need a more fundamental and theoretical background of system approaches. So the quality and quantity of system courses must be adopted to the specific programs. Wherever analytic approaches are taught, students should know that this is just one side of gathering knowledge that might be useful in applications and that a synthetic or systems approach is important too.

System thinking has a strong potential to serve various disciplines, including the areas of problem solving and basic research. The range of system courses must be designed in a way so that students can use what they have learned from sense making to practical and theoretical mastery of systems. Explicit system courses will be necessary in some education programs. In others system knowledge can be taught implicitly, i.e. through application.

3.1.3. Challenge: Addressing the Issue of Potential Demand for Systems Education

Changing the status of systems thinking to the level of a "scientific method" provides an enormous and challenging opportunity for systems education. In order to reach and educate a larger population of systems thinkers our mental model and assumptions need to change. This will require forums and debates in conferences and open publications on the future of systems thinking education. (The ISSS 2009 conference will be a great opportunity to take this debate to the next level).

In the case of university education, a basic level of systems understanding could be achieved through a course at the undergraduate level that deals with systems concepts in a generic way, and allow students from various disciplines to apply these to their own field of study. This type of course is recommended for offering as university or faculty core courses that are intended to provide a broad understanding of the systems addressed by the students' own programs and of the relationship between these and other systems affecting their operational environment. The core course should aim to broaden students' horizons and expand their appreciation of complexity. Students should be made aware of the demand from employers for graduates that can operate effectively in a 21st Century knowledge society by continuously emphasizing the need for an analytical framework to help them to critically analyze complex situations, solve problems and make decisions. These are generic skills that can be applied to any practical or professional field of employment, regardless of the particular field of interest.

3.1.4. Opportunity: The Potential for a Formal Approach to Spanning Multiple Disciplines

Can a systems approach be taught across a wide range of disciplines? As explain below the examples from existing institutions teaching systems, the answer is both yes and no. There are also many examples of systems approaches that have a cross-disciplinary appeal (such as system dynamics), and the basic goal of the founders of both general systems theory and cybernetics was highly interdisciplinary.

Part of the issue is that there are more than one kind of systems approach. Several authors have discussed the multiple schools that existing within the broad banner of systems thinking. For example, Ramage and Shipp (forthcoming) present seven traditions of systems authors: early cybernetics, general systems theory, system dynamics, soft and critical systems, soft cybernetics, complexity theory, and learning systems. Each of these traditions has a strong amount of commonality, and a certain overlap with other traditions, but also a considerable amount of difference.

So one key aspect of teaching systems across multiple disciplines is to recognize which form of systems is being talked about, what are its antecedents and its implications. It is unrealistic to expect a unified approach across all the different systems traditions, and when a university (including those listed below) teaches what it terms 'systems,' the selection of concepts and techniques is highly contingent on the experience of the faculty involved. Nonetheless, through a sense of the range of different perspectives involved, we can gain a clearer appreciation of the benefits of different systems approaches across multiple disciplines.

3.2. Systems Education at Institutions of Higher Education

Historically, the demand for systems education has been modest and there are only a handful of university-level systems education programs around the world. While the number of standalone systems thinking courses taught around the world is not small, the number of university-level programs or majors in the systems field is scant. There are two main reasons for this. First, the bulk of systems education to date has been focused on training specialists. This has naturally limited the potential population for systems education at both universities and among specialists at the professional level (i.e., internal and external corporate consultants, systems modelers, etc).

The second reason is related to the first, namely: the specialist focus has been accompanied by a relatively technical approach to systems education. This has left the impression that systems education is a technical subject suitable for engineers, scientists, quantitative ecologists and mathematicians and hence beyond the reach of other disciplines. This is reflected in the focus and language of most of the current text and reference books that are currently available. With the exception of a few and notably, *Systems Thinking and Modelling* (Maani & Cavana, 2007), the bulk of systems books are by-and-large hard to read and beyond the reach of most students, managers and policy makers.

The future growth of systems education will depend on how well systems educators around the world are able to relate systems thinking to topical issues and complex challenges managers and decision-makers are facing today. The list of these issues is large and growing daily: energy, food, sustainability, climate change, water shortage, and now credit crisis. The systems community can make a material contribution to the debate and resolution of these issues and hence should take a centre stage in these forums.

The systems field today remains largely fragmented. This is ironic for a field that claims to integrate other disciplines. Unless we are able to demonstrate to the world that system thinking is in fact an integrative discipline, we cannot convince the world to accept our precepts. This issue needs the close attention of the systems community.

University courses that teach principles of systems science without contextualizing them through case studies taken from the different areas of interest have little impact. This approach reduces demand for (and fosters an ignorance of the value of) systems education in later years when studies come to have the need for unraveling complex issues.

Universities around the world are addressing these issues in various ways. Some examples include:

3.2.1. The University of Queensland

The Master of Sustainable systems offered by the University of Queensland in Australia from 2010 (Bosch, 2008) is an example of a systems based postgraduate program that is designed to attract students from all faculties and disciplines across the wider university - from agriculture and science to engineering, business and health sciences (Figure 1).

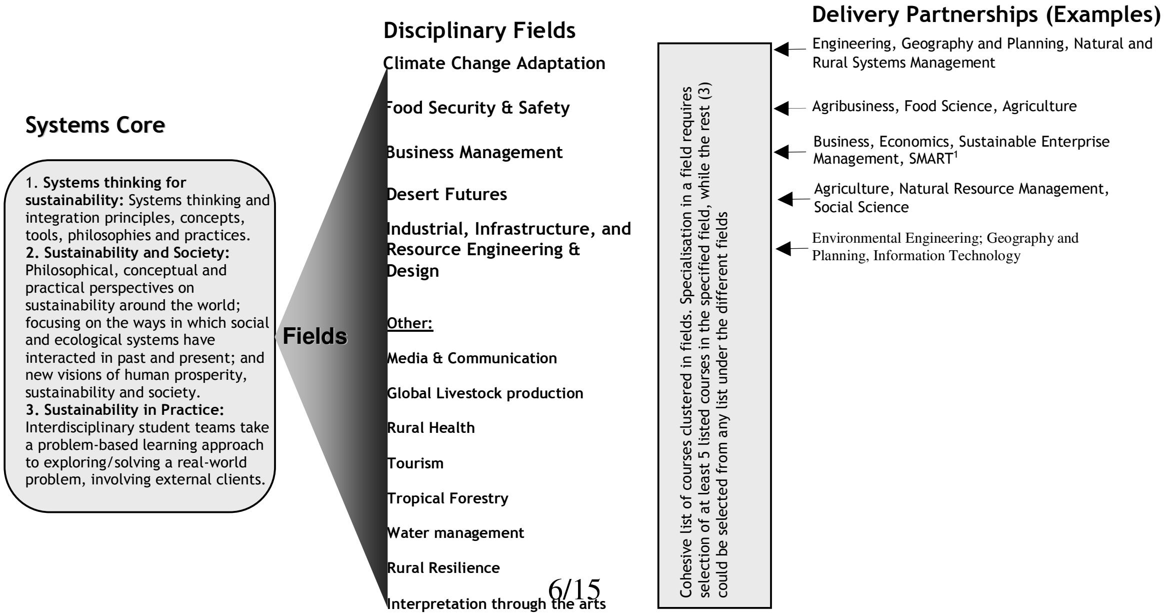

Figure 1. Design of the Master of Sustainable Systems, The University of Queensland, Australia.

Core courses include “Systems Thinking for Sustainability," which introduces systems thinking as a tool and scientific methodology for dealing with multiple domains and divergent interests and perspectives including natural-environmental, social-political, business-economics, and policy-governance. Decision making and policy formulation in this setting is complex and embeds uncertainty and distant time horizons, often creating unintended consequences, tradeoffs and compromises. This core course is designed to help students develop a systems (holistic) view of sustainability as well as gaining new tools and skills for dealing with its multifarious elements

Other core courses include “Sustainability and Society” which expands on the first by providing philosophical, conceptual, historical, and practical perspectives on sustainability around the world, focusing on the ways in which social and ecological systems have interacted in past and present; and new visions of human prosperity, sustainability and society. The capstone course “Sustainability in Practice” integrates system tools, theories and concepts learned in previous courses. It involves multidisciplinary group projects as the key component of the course.

3.2.2. Open University

The Open University (OU) is Europe’s largest distance learning university, with around 200,000 students enrolled. For more than 35 years (most of its existence), it has had a systems group, based in the Faculty of Technology (now part of the Faculty of Mathematics, Computing and Technology), with at least 30,000 students taking its courses. As with most other UK universities teaching systems, the approach of the systems group has always been highly pragmatic, oriented towards understanding systems and change management in organizations. In particular, the OU systems group has been highly influenced historically by systems engineering and by soft systems approaches such as the work of Peter Checkland, Geoffrey Vickers and Russell Ackoff; and more recently by critical systems thinking and second-order cybernetics.

Teaching at a distance has the great advantage of reaching many students otherwise unable to access higher education, but is difficult in a subject such as systems where an apprenticeship model of education is often typical. The OU has instead emphasized the teaching of methodology, in a largely systematic form; and also the strong use of qualitative diagramming as a teaching tool which can create powerful models in a way that can both be taught and applied at a distance (Lane and Morris, 2001). Historically, the distance teaching through textbooks and television programs was supplemented by face-to-face tutorials and annual week-long ‘summer schools’; both of these methods have become less prominent over time, and the last OU summer school in systems was held in 2008.

The OU’s teaching of systems is conducted quite differently at the undergraduate and postgraduate levels. At the undergraduate level, the focus has been on a general systems approach – a set of common techniques applied across a wide range of disciplines. The OU has historically been oriented towards modular ‘courses’ rather than complete degree programs (six full courses being the requirement for an undergraduate degree), and for most of thirty years the offering within systems has been just two such

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[1] Sustainable Management Alliance in Research and Teaching – a collaborative partnership initiated by the School of Natural and Rural systems Management to bring together some of Queensland’s leading business people with the ultimate goal of informing and enhancing innovative research and industry guided teaching in the field of sustainable enterprise management.

courses – one at second level, the other at third level. The main goal of the second level course is to teach a set of core systems concepts, diagramming techniques and basic modeling. The third level course has a much greater focus on methodology and practice.

At the postgraduate level, the OU has largely had applied Masters programs aimed at various groups of professionals, because of the need for systems approaches to be taught in the context of a specific application area. All of these programs tend to be highly vocational, in subjects including information systems, environmental decision-making, technology management and global development management. While the explicitly systems content of these programs varies, each of them is strongly based on systems approaches. Over the past few years, the OU has been developing a more generic Masters program in systemic practice, applicable to professionals across a wide range of disciplines, which will start in 2009.

3.2.3. Shibaura Institute of Technology Graduate School of Engineering Management (MOT Program)

As of this writing, Shibaura Institute of Technology Graduate School of Engineering Management (MOT Program) offers the following systems-related courses:
(1) Social Systems Sciences ("Why" and "What" aspects of systems thinking.)
(2) Qualitative Systems Analysis ("How" aspect of systems thinking)

A unique aspect of these courses is that they represent two completely different systems thinking schools. By contrast, it is often the case that systems courses offered from a university department tend to be clustered around one systems thinking school or another.

The "Social Systems Sciences" course is based on Idealized Systems Design by Russell L. Ackoff and Fred E. Emery at the Social Systems Sciences (S^3) Department of University of Pennsylvania, circa 1984. MOT students often comment that this class helps them to question the question and identify the real issue behind the problem symptoms.

The "Qualitative Systems Analysis" course is based on the method developed by Howard L. Harrison and Robert J. Miller at the Sociotechnical Systems Design (STSD) Program at the University of Wisconsin-Madison, circa 1976. This course was derived from Systems Dynamics of J.W. Forrester, and is meant to help people make sense out of a complicated problem system using static and dynamic systems diagrams. "(STSD's) purpose is to provide instructions for social science students in two areas... technological information (and) certain concepts and techniques used by engineers which can be of value to social-science graduates in pursuing their careers." ("Sociotechnical Systems Design Program" Announcement, 1976).

3.3. Key Learning from Past Research in Systems Science

Our quest for improved systems education at the university level can be informed by extant research in systems sciences.

3.3.1. Quotes and Key Ideas from Systems Luminaries

"In the second stage (of evolution), easier-to-apply *indexes* that correlate highly with expert judgment are sought . . . The third stage of the evolution is the development of idealized operational definitions and measures of the properly involved . . . Very few of the so-called measures in the behavioral sciences have gone beyond the second stage of this evolution." (Ackoff and Emery, 1972, p. 159) The same could apply to systems education; namely, very few systems education program are in the idealized state of the third stage, while there are a good number of the second stage systems education programs. Ideally, a systems education program should be run as a purposeful system..

"(I)t is not nearly as important that a student learns any particular subject as it is that he learns how to learn and how to enjoy doing so . . . (S)tudents should be free to design their own curricula . . . It is at least as revealing of a student's quality to evaluate the curriculum he has designed as it is to evaluate what he has gotten out of it." (Ackoff, 1999, pp. 163-64) Ideally, systems education departments should be an open, purposeful system in which students can design their own learning ends, and not just receiving courses for pre-fixed goals by the department.

Ackoff et al established the Social systems Sciences (S^3) Ph.D. Program at The Wharton School of the University of Pennsylvania (1974-86) as an interactive, self-learning program for the students, as an idealized systems design of higher education. S^3 was a bold attempt to advance social systems sciences as a scientific discipline as well as practical problem-solving method for real-world problems, such as designing educational systems, information systems, management tasks, etc. An extraordinary feature of the S^3 is that the Committee of the Whole Meeting, with each faculty member, student and administrator cast one equal vote, made decisions about S^3 policies and operations. Also, at S^3 admissions was handled by student-faculty admissions committee.

3.3.2. Past Insights that Warrant Further Investigation

Start systems education from early childhood, continue it through elementary education all the way to the high-education. Start systems education when children are very young. Systems thinking could be natural talent of children (Horiuchi, 2003; Banathy, 1996).

Merrelyn Emery states, "I think there's a lot of groundwork that needs to be done in getting some open systems principles built into the education system right from the start and to get away from this 'top-down' teaching which has been dominating our concept of education." (Barton et al., 2004, p. 25)

3.3.3. On the Importance of Remaining Inclusive of Pluralistic Views

There are various systems approaches, such as those of Ackoff, Banathy, Checkland, Emery, etc. Systems education departments tend to focus on a single systems approach. Each systems thinking approach is holistic and complete unto itself. And yet, each systems approach is unique and different from the others. Hence, it is desirable to include an introductory course consisting of an overview of various systems approaches before going into one specific systems thinking approach.

In line with the discussion in section 2.1.5 above, Merrelyn Emery argues that "I don't think that there *is* a systems community. There may be several and they don't seem to have a lot of understanding of each other...." (Barton et al., 2004, p. 26). Bob Flood adds, "Ironically I think in the wider span of the systems movement there is a lack of tolerance between different schools of thought and I think that's very destructive." (Barton et al., 2004, p. 26)

4. An Overview of the Systems Education Matrix

4.1. Structure

The structure of the System Education Matrix (SEM) is given by its two axes. As the horizontal axis is divided into three areas and the vertical axis into two areas, the matrix results in six distinct cells. Each cell maps a particular systems education program. In the following the axes and the cells are described in detail.

4.1.1. The Two Axes of the Systems Education Matrix

Through the above described process, we came to realize that differences in systems education are based on two main axes: the depth and type of systems knowledge required (from sense-making over practical mastery to theoretical mastery), and whether systems concepts are taught *per se* (generic) or rather through application within one or more specific disciplines (discipline-integrated). The result is the Systems Education Matrix, which -- according to the two axes -- identifies six types of recipients of systems education. The table below illustrates the results.

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1. Sense-Making			**2.1. Practical Mastery (with ability to add to the knowledge base)**	**2.2. Theoretical M (with ability to pra**
e.g., horticulturalist, accountant	**A. Discipline-Integrated**		e.g., systemic horticulturalist	e.g., creator of kno within sy horticulture
systems student	**B. Generic**		systems practitioner	creator of s knowledge

In the **columns** the different categories of depth and type of systems knowledge are depicted. The capacities which apply to people who would receive education at the levels defined by the three columns are:

1. Sense-making: This involves having the ability to use basic systems concepts to make sense of phenomena, objects and processes in the world. This includes for example the capacity to:

a. see things holistically
b. understand interconnectedness
c. recognize the interests on stakeholders representing one or more interacting systems
d. identify underlying problems rather than symptoms

2.1. Practical mastery (with ability to add to the knowledge base): This relates to having the ability to competently use or apply systems concepts for research or practice. The ability to expound upon or teach systems concepts to others. This includes for example the capacity to (items included above, plus):

a. be creative in problem solving
b. effectively manage messy, ill-defined situations
c. adapt effectively to changing environments
d. apply critical reasoning within multiple levels
e. effectively intervene in problematic situations
f. apply systems design approaches
g. facilitate integration across disciplines

2.2. Theoretical mastery (with ability to practice): This refers to being in a position to add competently to the body of systems knowledge (viz., philosophy, theory, methodology, and praxis), as well as areas of practical application in specific contexts. This includes for example the capacity to (items included in *1. Sense-making* above, plus):

a. integrate knowledge across disciplines
b apply critical reasoning within multiple levels
c. effectively understand changing environments

  d. deeply understand multiple systems approaches
  e. refine and/or develop new system approaches
  f. facilitate connections between multiple systems theories and practices

The two **rows** are distinguished by the width of scope to which the system approaches should serve; i.e. if the graduate student should work in a distinguished discipline or rather beyond the boundaries of a discipline. The capacities of the rows include:

A. Discipline-integrated: This is having the ability to integrate systems approaches into one or more disciplines or areas of application. This includes for example, the capacity to:
  a. understand how their field of interest fits into the bigger picture
  b. deepen their understanding of their own discipline or area of interest by introducing systems concepts

B. Generic: This concerns having the ability to understand, apply, and relate systems concepts in multiple contexts and/or to add to the systems knowledge base. This includes for example, the capacity to:
  a. develop a broad knowledge of systems approaches
  b. identify meaningful and potentially useful patterns among multiple disciplines or areas of knowledge
  c. develop potentially useful, systems-oriented theories, methodologies and techniques which can applied in more than one discipline

4.1.2. The 6 Cells of the Systems Education Matrix

In the six cells of the table the different goals of systems education are reflected. Each cell corresponds to a basic type of systems education, i.e. distinct education programs a university might want to offer their students. A detailed description of each of the cells, from A1 in the top left corner to B2.2 in the bottom right corner, together with examples of potential participants is given in the following.

A1 – Discipline focused with ability to use basic systems concepts to make sense of phenomena, objects and processes in the world.

A basic level of systems understanding could be achieved through a course at undergraduate level that deals with systems concepts in a generic way, and allow students from various disciplines to apply these to their own field of study. This type of course is recommended for offering as university or faculty core courses that are intended to provide a broad understanding of the systems addressed by the students' own programs and of the relationship between these and other systems affecting their operational environment. The core course should aim to broaden students' horizons and expand their appreciation of complexity.

An additional focus of such a generic core course will be to assist students to start to develop some of the skills and attributes required for effective university undergraduate study and transition to employment. These include attributes such as effective communication skills, independence, creativity, critical judgment and ethical and social understanding.

A2.1 – Discipline-Integrated, with ability to competently use and apply systems concepts for research or practice.

The educational programs to develop this type of competency could be available at both under and postgraduate (Masters) programs. An undergraduate example is the Bachelor of Applied Science at the University of Queensland, Australia (see above) which develops an integrated and systems approach to management and policy decisions about the multiple uses of agricultural land, rangelands, forests, water, and marine resources. The design includes a systems core of integrative courses in natural resource systems, economics, social science, management, and policy; and a range of quantitative and qualitative skills and tools for systems thinking, identifying leverage points and systemic interventions, systems dynamics and modeling, problem solving and development of decision-support systems. Clusters of discipline focused electives provide students with an opportunity to apply the systems approaches to their specific area of interest (e.g., Tropical Forestry, Resource Economics, Coastal Environments, Natural Resources, Socio-Ecological systems, Rural Development, Indigenous Perspectives, Mining, Desert Futures).

A2.2 Discipline-Focused, but in a position to add competently to the body of systems knowledge and theory

People who are trained in this area are in the position to extend the systems knowledge in a certain discipline or several disciplines. They are working on the concepts and approaches which are used in the domain of A2.1. During the training theoretical mastery is achieved through higher degree research in post-graduate education. Students must profoundly understand the disciplines they are dealing with and also the advantages and shortcomings of various systems approaches in order to perform research and enhance the theoretical knowledge base.

B1, B2.1 & B2.2 Generic

At present, the generic field is quite limited, as there are only a handful of universities around the world who train systems generalists. Nevertheless, to make a real impact, the systems community should not only focus on systems education for specialists. While we need systems theoreticians and researchers, the key leverage is not to make ‘systems’ a mainstream science, but rather to integrate systems education into mainstream disciplines and degrees (the "A" cells in our matrix). Indeed, some generalists are needed who can take into account the system approaches within several disciplines and who are able to deal with the bigger pictures of the situations they encounter.

People fitting the B1 cell would be a student of systems science who are in the position of making sense of problems in various disciplines and between disciplines. The knowledge she/he gained allows for quickly finding key issues that are not obvious to people trained and operating only in single disciplines.

Somebody trained in the B2.1 field has a broad knowledge of system concepts and approaches that can be practically useful in various areas. How to apply those concepts and approaches is known in detail. This also includes the ability of working together with different stakeholders and the ability of guiding the work process.

People working in the B2.2 field are able to conduct research on a generic conceptual or theoretical basis. Thereby the systems knowledge base is extended. Here also approaches that are useful in one area can be checked to find out if they are useful in other areas too, or whether there is a potential to generalize them. This is the domain of PhD students and researchers.

The generic fields of systems education might be compared to the teaching and research for instance in the theory of probabilities or statistics. A B1 statistician would be an undergraduate student of statistics; a B2.1 statistician would be somebody who is able to apply the broad knowledge of statistical concepts to a wide range of problems; and the B2.2 statistician would be somebody who is working on the concepts themselves. This simile might help to further develop generic systems education programs.

4.2. How the Systems Education Matrix Can Be Used

The Systems Education Matrix can serve as a useful tool for educators charged with designing new university-level curricula that effectively integrate systems concepts and/or teach those concepts explicitly. The matrix undoubtedly stands to be further improved upon and refined, but it can be potentially used as it exists in its current state.

The descriptions of the different types of systems education required (and acknowledging that these differences do exist) could serve as useful guidelines to develop educational programs that will comply with the needs of the different types of students. It would further be useful to use these cells as guidelines to map the relevant systems concepts that would contribute to the development of the skills that would be required and be of use to the different types of students. Although such a generic mapping of concepts could be valuable, this task should rather be left to individual educators within the contexts of their own disciplines. It is also important to recognize that different universities (and study programs) specify different attributes that will be expected from their graduates. These should be taken into account in the development of course content and curricula to ensure that the systems education will be meaningful. This will not only lead to students accepting the value of systems thinking and tools as an integral part of their disciplines (as in the case of statistics), but also increase the demand for systems education.

It should be acknowledged that, although the systems content of courses is of utmost importance to achieve the goals of systems education, the quality and mode of delivery is equally important (Maani, 2004). “Capstone courses”, in which students have the opportunity to integrate the tools, theories and concepts they have learned in real world problems involving multiple dimensions.

5. Questions for Future Iterations of the Ongoing Dialogue on System Education

There remain a number of aspects of the issue of systems education to be explored. For example: What are the goals of systems education? Each systems education program needs to define for itself which elements of "systems education" it will teach. For example: Systematic (i.e., being comprehensive, consistent and deliberate in one's method) versus systemic (i.e., taking into account the nature and potential impacts of multiple dimensions of a system and its environment), design versus science, and, design versus art (derived from Banathy, 1996). Is the program to provide an overall picture of systems thinking? Or, is it to be focused on a particular systems approach? Is the program about systems thinking itself, or is it to be taught in a systemic way by employing systems thinking techniques? “We have shown that the maturation (of systems thinking) involves both conceptualizations about systems and practical engagements with systems (or, alternatively, with fields construed in systemic terms)” (Barton et al., 2004, p. 31).

Ideally, those former students who have learned systems thinking should be able to facilitate communication among various disciplines. Also, they should be able to identity the real, underlying problems, synthesizing various disciplines.

The next step in this dialogue seems to be to define the term “systems education” and to design it from an idealized design perspective before going into the specifics of elaborating upon the details of the matrix. We could define two ideal images: (1) A purposeful systems-education system to educate systems-science generalists, and (2) A purposive systems-education system to educate specialists working in non-systems-related fields to have a deeper, fuller understanding of systems thinking. Such an idealized systems design process could take up another full conversation cycle.

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