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Course Design Principles to Support the Learning of Complex Information Infrastructures

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Abstract

This paper presents an integrated, learning-centred course design for studying the complex, rapidly changing information infrastructures underpinning organisations and society. Students need to develop an agile, critical mindset in order to influence and be influenced by these socio-technical systems in ways which enhance information management, control and innovation. There are several challenges to developing this mindset. Students and technology vendors often expect technical training and current educational materials reinforce this approach. A silo-based structure to most degrees exacerbates the problem. The complexity of context and rapidity of change often get lost in the mix. This paper addresses these problems and makes two contributions. It models an information infrastructure as a complex adaptive system (CAS) with particular characteristics. It suggests design principles to support the learning of complex information infrastructures by extending the learning context in Whetten's learning-centred course design. An educational ecosystem, supported by integrated case studies underpins this design.

Keywords information infrastructure, integrated design, learning, complexity, CAS

1 Introduction

This paper addresses the issues that arise in facilitating student learning regarding information, or digital infrastructures. These infrastructures are socio-technical in nature, both affecting and being affected by the people using them. They are highly complex, rapidly evolving, span organisations and indeed whole societies, have no clear boundaries and do not respond to top-down control. They have received increased attention at both a theoretical (Hanseth and Lyytinen 2010; Henfridsson and Bygstad 2013; Rodon and Silva 2015) and practice level (World Economic Forum 2014). To engage with these infrastructures demands a nuanced understanding of their integrated, yet chaotic nature, and an agile mindset to engage with the rapidity of change. It is only with this mindset that students can develop working practices that ensure effective information infrastructures management and control. Developing that mindset in students is critical to their employability (McCowan, 2015). Recent reports show that over the next two decades close to 5 million Australian jobs will be affected or replaced by computerisation and technology (CEDA 2015; PwC 2015).

To develop this mindset, Business Information Systems (BIS) education needs to address two problems. The first of these is the assumption by many students and technology vendors, that what is needed is technical training in specific products. The opportunities for embedding information infrastructure education in curricula are more far-reaching than instrumental technical skills. Further, this training, often obsolete by the time students finish their degrees, does not reflect the reality of the information infrastructures that such students face in industry. What is required instead is a translation of the complexity of infrastructures into an educational context, an enormous challenge, which leads us to the second problem. Simulations can assist the analysis and design of complex processes associated with an infrastructure, but require a detailed understanding of the content and context (Bekebrede et al. 2015). While the value of simulation based education (SBE) is widely recognised for providing a bridge between the classroom and the work environment, Fenwick and Dahlgren (2015, 360-361) further argue that developments tend to: 1) focus on the "high fidelity of the technological environments than on the pedagogies aiming to maximise the outcomes of these environments;" 2) emphasise the mastery of "procedural skills" rather than responding to complex scenarios that require interdisciplinary approaches; and 3) lack a robust theoretical foundation. It is only by understanding the links and boundaries between different aspects of infrastructure that students can embrace the holistic picture.

BIS education also needs to embrace changes to many of the fundamental tenets of higher education. First, educational technologies present us with different possibilities as to how, where and when we learn, focusing the individual at the centre of a learning system. For example, as knowledge becomes more fluid across disciplines and university/industry boundaries, the place of epistemic authority that has underpinned traditional educational models is being questioned (Burden et al. 2016, 7,8). Yet the nature of degree programs is still very much silo-based. Second, there is an increased recognition of the impact of the material dimension (e.g., objects, technologies, tools, texts, discourses etc.) in learning (Sørensen 2009; Fenwick 2010; Fenwick et al. 2012) challenging existing theoretical assumptions that the student and socio-cultural aspects are the defining parameters for "what it means to learn" (Fenwick 2010). Therefore there is an imperative for novel approaches that promote knowledge integration, take a socio-technical perspective and engage learners in active learning across boundaries.

This paper reports on the first stage of a systematic approach to a course design that will enable student learning regarding information infrastructures. Specifically:

- It models an information infrastructure as a complex adaptive system (CAS), and in particular provides a graphic representation which can be repeatedly used across subject areas to reinforce the complexity and integration between the components. This theoretical approach reflects previous literature in this area (see, for example, Hanseth and Lyytinen 2010).
- It presents an extension of the learning context model developed by Whetten et al. (2009) to incorporate the complexity inherent in such information infrastructures. The model is then used to recommend design principles underpinning an integrated learning approach across multiple subject areas comprising the information infrastructure. Supporting this design, is an *educational ecosystem* that will: 1) mirror the complex information infrastructures we have to convey in the classroom; 2) assist in the development of innovative and technology-enhanced curriculum and materials; and 3) improve student learning outcomes and capabilities to succeed in digitally-driven dynamic environments.

Specifically, we start with an analysis of three subject areas we teach and a review of a learning-centred course design used in management education. This analysis highlights special challenges arising from the complex nature of the technologies we teach as part of the *information infrastructures* organisations implement and rely upon. We draw attention to how these infrastructures are more than simple background context by conducting an in-depth holistic assessment of our learning context.

The paper first presents the learning context. A CAS lens is then used to explain the *specific* characteristics and behaviour exhibited in information infrastructures. A specific design is then discussed, based on an extension of Whetten et al's (2009) Learning Centred Course Design model. A discussion follows on the special challenges we encounter implementing the learning-centred design in our complex socio-technical context, and ways forward to overcome these challenges by adapting this educational model.

2 Subject Areas Conveying Information Infrastructures

Enterprise Systems (ES) are standardised, integrated software solutions, based on "best practice" industry solutions and are offered as off-the-shelf packages from different vendors, such as SAP and Oracle, two of the market leaders. ES manage organisational resources by integrating information flows across several functions into a single system to serve the needs across different departments in an organisation. There is an extensive literature regarding the way in which these systems shape, and are shaped by the organisations in which they are implemented (see for example Berente et al. 2010; Leonard and Higson 2014; Schubert and Williams 2011). In introductory courses, students explore such systems as they apply to individual business processes such as procurement or fulfilment. In advanced, elective courses, there is a focus on the highly integrative nature of these systems, and the way in which these affect and are affected by, the day to day practices of human agents.

Business process management software (BPMS) is an application that aims to support streamlining business processes and workflows in order to increase organisations' efficiency and adaptability to ever-changing environments. These applications are used in BPM and allow companies to manage entire process life cycles by defining and maintaining "best practices" in their processes. As such BPMS are seen as valuable tools for developing and improving business processes by: 1) tracking how information is used, 2) mapping business processes, 3) ensuring that transactions are done correctly, by showing where data and process bottlenecks occur, and 4) highlighting deficiencies, including areas where resources are wasted, allowing organisations to improve their processes. Again, introductory courses illustrate the use of such software on individual processes, and links this to the way in which ES are then used to support those processes. At the advanced, elective level a more comprehensive approach sees students looking at business process architectures at both intra and inter organisational levels.

Governance, Risk, and Compliance (GRC) systems consist of a vast array of technologies and approaches that are designed to assist organisations integrate, manage and oversee multiple risks, compliance obligations and control functions (Hardy and Leonard 2011). Introductory courses explore control issues in individual processes. At the advanced level, a more comprehensive framework is applied by exploring risk identification and assessment, risk and control monitoring, policy management and value creation and preservation at the governance level.

Common across these subject areas are technologies that have both information and processes at the heart of their functionality and that interact in a holistic manner. A major challenge and the focus of our work is the fact that in the "real world" these technologies never exist in isolation as indicated by the arrows in Figure 1 (see next page). ES provide a "backbone" of support for executing complex, integrated processes, such as end-to-end customer order management and policy management as part of a GRC suite of products. These processes are managed and improved using BPMS that may incorporate risk and control processes.

3 Characteristics of Information Infrastructures as Complex Adaptive Systems

In Figure 1, any one of the arrows represent multiple interactions at any one time and their effect leads to a holistic emergent behaviour that is more than a simple sum of a system's parts. These interactions can change over time. Consider, for example, the implementation of an ES and how the system imposes its own logic in an organisation, often restricting the way business must be performed (i.e., changing business processes that will be documented and managed using BPMS) and reducing employees' flexibility or leading to changes in employees roles (Volkoff et al. 2007). Human agency, too has its effects. Sometimes the intended system changes are resisted (Doolin 2004). Often, human invention leads to tinkering, or bricolage, so that the system use "drifts" away from the original strategic intent (Ciborra 2000). In addition an information infrastructure interacts with its environment. For example legal, regulatory factors impact on how ES are configured and used in various jurisdictions, as well as how information is processed, accessed and protected; in other words the system co-evolves with its environment.

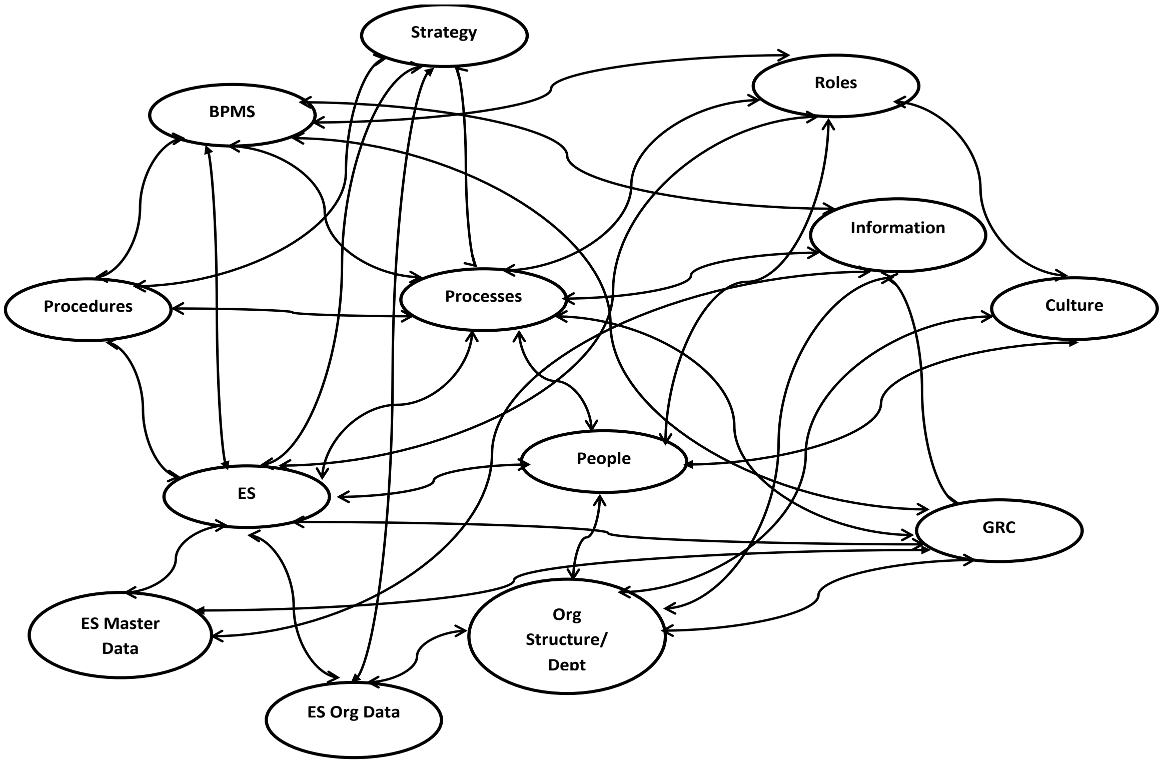

Figure 1: Information Infrastructure as a Complex Adaptive System

Rinaldi et al. (2001) argue that all infrastructures are complex collections of interacting components in which change occurs over time. To assist us understanding and addressing the complexity inherent in such infrastructures, we turn our attention to key characteristics of complex adaptive systems (CAS) set out in Table 1. Drawing upon Rinaldi et al. (2001) and the description of the interactions represented in Figure 1, we argue that the information infrastructures we teach in the classroom are typical examples of CAS.

The existing literature (see, for example, Allen and Varga 2006; Benbya and McKelvey 2006; Raduescu and Gill 2012) notes that CAS have specific characteristics (see Table 1) that make them more difficult to understand, analyse, learn, and manage. In employing a CAS perspective, we first identify the special challenges these characteristics bring to our course design. Second, despite these challenges, we argue that CAS presents an opportunity for developing a learning-centred design by acknowledging a socio-material dimension. It is worth noting that when engaging with CAS, both educators and students must acknowledge concepts such as variability, adaptation, uncertainty, and non-linearity to facilitate an improved understanding of how co-evolutionary processes and new dynamic patterns emerge over time (Benbya and McKelvey 2006). With this mindset shift, our aim is to "foster students abilities to integrate their learning across contexts over time" (Huber and Hutchings 2004; 1) and develop more agile working practices.

Characteristics	Description
1. Agents autonomy	Agents are autonomous, subject to simple and localised rules or norms. There is no central control; however their behavior is not entirely random.
2. Connectivity and interdependence	Agents engage in interactions as there is a high interdependency among all components, often bi-directional. A CAS needs to be studied as a complete and interacting whole rather than as an assembly of distinct and separate agents.
3. Context awareness	A CAS is sensitive to initial conditions or context. These conditions lead to different and unanticipated effect despite the fact a system follows the same trajectory.
4. Eco-system structure	A CAS system has sub-systems and is part of a larger system/s. Each system operates in a nested structure of interconnected sub-systems that interact with each other.

5. Non-linearity	Agents interact in a non-linear way, leading to unknown behavior. The system is highly sensitive to internal and external influences leading to the well-known butterfly effect ("small inputs yield huge effects").
6. Emergent behavior	The connectivity, interdependence and interactions among agents determine the aggregate behavior of the whole system; holistic patterns emerge bottom-up.
7. Self-organisation	New forms may suddenly result from interactions within the CAS in response to changing conditions or disruptive events.
8. Adaptation	CAS often react to changes in environment by taking advantages and adapting themselves. The system adapts to survive or sustain coherence (equilibrium).
9. Co-evolution	CAS co-evolve with their environment; changes in environment lead to changes in their structure and behavior, which in turn lead to changes in the environment.

Table 1. CAS Characteristics (adapted from Allen and Varga 2006, Benbya and McKelvey 2006, Raduescu and Gill 2012)

4 Extending Whetten's Learning Context to Support the Study of Complex Information Infrastructures

We extend Whetten et al's (2009) "Learning-centred course design" model as a basis for addressing the specific challenges in supporting student learning of complex information infrastructures. Whetten et al.'s model presents a systematic process for designing curriculum in management education grounded in a paradigm shift: from a *focus on teaching* to a *focus on student learning*. The model, contains three interacting design elements: "*significant learning objectives*, *developmental learning assessment,* and *engaging learning activities*" to produce a coherent learning experience. Underpinning the three design elements is the "*learning context*" (Whetten et al. 2009, 258), with six key situational factors: the specific context of the teaching and learning situation, the expectations of external groups, the nature of the subject, the characteristics of learners, the characteristics of the teacher, and special pedagogical challenges.

Whetten et al. (2009) recommend beginning with a systematic assessment of the learning context as the first step of a "comprehensive approach to course design;" hence our starting point. A detailed review of the range of situational factors in the learning context of our curriculum is reported elsewhere (Leonard et al. 2013). In this paper, we build upon this earlier examination to discuss the specific problems related to each factor. Table 2 presents a summary of the context, and it is discussed further below.

Specific context of T&L situation	Expectations of external groups	Nature of subject	Characteristics of learners	Characteristics of teachers	Special pedagogical challenges
Silo practices in education system.	Provision of "training" materials.	Complex adaptive sociotechnical system.	Expectation of technical training.	Preference for socio-technical approach.	Unknown workplace and dynamic technologies.

Table 2. Extension of Whetten et al.'s Learning Context Situational Factors

4.1 Specific Context of Teaching & Learning Situation: Silo Practices in the Education System

The technologies we teach form a CAS and they should ideally be taught in a system as a whole, because they cannot be understood in isolation of each other. The current structure of our degrees with each unit of study capturing an individual technology being taught in isolation from each other is at odds with this. Furthermore, students can enrol in each unit at any point during their degree: our degrees do not follow a pre-requisite model for student progression. This limits the learning design options we can take to teach the integrated nature of these technologies, explore the rich interactions, and understand their emergent behaviour as a whole, rather than in isolation.

In addition, complex problems cannot be fully understood or solved when approached from single disciplines. Inter-disciplinary education suggests that better solutions to complex problems result from a combination of perspectives that different disciplines can provide. Students need to learn how to respond to challenges that transcend disciplines, work at the intersections of multiple disciplines, and develop solutions that do not conform to standard disciplinary paths.

4.2 Expectation of External Groups: Training Materials and Skill Focus

While some external groups, particularly employers, may emphasise the requirement for students to understand the complexity of a modern information infrastructure, others do not. Some employers expect technical training in specific subjects. This is reinforced by the view of some (though not all) of the technology providers who supply parts of the educational ecosystem under discussion in this paper.

4.3 Nature of the Subject: Understanding Complexity

The major challenge we face is conveying an understanding of the complexity inherent in these information infrastructures. Various components in an information infrastructure system could engage at any point in time in non-linear interactions that lead to spontaneous and self-organised behaviour. Such behaviour is unpredictable and relates often to unclear or unknown underpinning causes. For example, in practice ES implementations face unpredictability/uncertainty and limited controllability. Potential reasons are changes in the business context and surrounding environment that could occur during an implementation lifecycle that can span three years or more. Often, ES implementations are characterised by effects quite distant from what was originally intended outcome (Berente et al. 2010; Leonard and Higson 2014). Causal logic does not necessarily apply when trying to understand such complex behaviour and it might manifest in the grey area between predictability and unpredictability.

Although these concepts are extremely helpful to theoretically explain the role of interactions among CAS components, in reality it is extremely difficult to teach them in a classroom in absence of their manifestation in the real world. Firstly, students are not familiar with CAS thinking, as the more structured, rational, and predictable paradigm is often easier to follow and understand. Secondly, many students have not experienced any of these technologies in the real world, and teaching them separately is also current common practice. Translating the complexity of information infrastructures can therefore be quite difficult and the key question we face is how to reconcile the “shape” a CAS takes in a teaching environment, thus overcoming the inability of students to deal with complexity.

4.4 Characteristics of the Learners: Expectations in Student Populations

Students often perceive the benefits of BIS courses as technical training, rather than a development of the boundary-crossing skills required in a competitive knowledge based-economy. For example, an ES is a very important technology for doing business, and almost all businesses have some type of ES (Luftman et al. 2012). It is much more than a technology, as it involves new mindsets for doing business and requires organisational changes including their strategy, structures, business processes and culture (Hustad et al. 2014). Therefore the socio-technical complexity of an ES requires diverse skills and rigorous expertise far beyond the pure technical proficiency (Markus 2004).

4.5 Characteristics of the Teachers: Preference for Socio-technical Approach

Among current staff delivering these units, there is considerable content-related academic and industry experience, particularly multi and inter-disciplinary knowledge and expertise in the areas of BPM, project management, change management, accounting, audit, control, risk management, and SAP. There is a consensus of opinion of the need to communicate the complex socio-technical nature of the business world to students. Developing the required skills in teaching with and about complex systems requires combined efforts and continuity in the subject areas. In addition, each academic has their signature pedagogies on how they interact with students, how they engage with the material, their attitudes, beliefs, all shaped by their different personal and professional experiences. Synergistic pedagogies are required to design integrated and purposeful learning approaches for these complex socio-technical environments. This is reinforced by the academic staff whose research is sensitive to the “messiness” of information infrastructures and socio-technical approaches (see for example, Hardy 2014; Hardy and Tolhurst 2014; Leonard and Carroll, 2010; Leonard et al. 2013; Raduescu and Gill 2012.)

4.6 Special Pedagogical Challenges

“Learning and teaching today aims at preparing students for job that don’t exist yet, using novel technologies, not invented yet, in order to solve problems unknown today” (Fisch et al. 2012). Today’s students face a double challenge when they enter the workforce: in addition to facing a complex socio-technical environment, they also face one in which the technological components are unknown. A key requirement for the future workforce therefore is the ability to respond to the increasing pace of change and external disruption in the environment. Our future graduates must be agile in the face of business uncertainty and change. While the need to prepare for these unknowable futures is widely recognised, there is an imperative to better understand the content, context and consequences of these changing landscapes to progress our imaginings of future business education. For graduates to be agile and adaptable to unpredictable socio-technical landscapes, dynamic learning capabilities are required to articulate and stimulate the necessary action.

Technology may change radically in the three to five years it takes a student to complete a degree. Once they enter the workforce, that change will continue. The rapidly changing nature of technologies and business contexts affects the type and range of materials and data available for academic education. We rely on commercial training materials that are not designed by and for the academic environment. We also do not have immediate access to the organisational environment in which these technologies operate. Besides the fact that we lack the contextual or organisational data, we also must keep up with rapid rate of change in this data; what an organisation looks like in five years can be very different from what it is today.

For example, when running process analysis and simulation in BPMS, assumptions must be made about different data including duration, costs, and resources allocated. Without having access to business users, documents, and rules, it is extremely difficult to perform a full analysis of current processes as well as obtaining realistic results from simulation. The hands-on SAP exercises are based on training materials and case studies that cannot convey the complexity that comes with the scale of ES. We also face issues related to how assurance tools deal with messy data. In addition, we are challenged in conveying the contextual understanding of the organisational environment and how these technologies operate in the real world because the training materials lack an integrated view of the business contexts in which technologies integrate and operate (Leonard et al. 2013). Conveying this level of integration without a physical implementation is therefore very difficult in a laboratory environment. Furthermore, without access to the environment, the ability to understand the context awareness and co-evolutionary processes is limited.

5 Integrated Course Design Principles to Support the Learning of Complex Information Infrastructures

In order to solve the problems identified in the Learning Context Situational Factors, we now turn to Whetten et al.'s (2009) design elements, as illustrated in Figure 2. This figure includes the specific objectives, assessments and activities relevant to our specific design, and also extends the model to include an integrative case and educational ecosystem.

5.1 Formulate Significant Learning Objectives

In referring to CAS characteristics we should aim to formulate explicit learning objectives that will provide a wide range of benefits for both teachers and students in the learning process. Educators should set up a course design on competencies that are both relevant and personal for students in their future. When formulating learning objectives, the focus should be on promoting a common set of values across the subject areas, hence mitigating the silo effect. More emphasis should be on those that recognise that: 1) many phenomena and problems under study are inherently unstable and uncertain; 2) solutions to problems, transformations, and change cannot be understood in linear or mechanical terms; 3) diversity and collaboration must be recognised and promoted as a source of possible response to unexpected or emergent situations; 4) students although are autonomous learners, they belong to a collective knowledge-producing system through shared ideas, insights and projects; 5) there is no single version of the truth and the development of interpretative reach is also required; 6) different angles and perspectives are required when analysing complex situations; 7) value can be created as a result of making sense of the contrasting or conflicting insights and arguments.

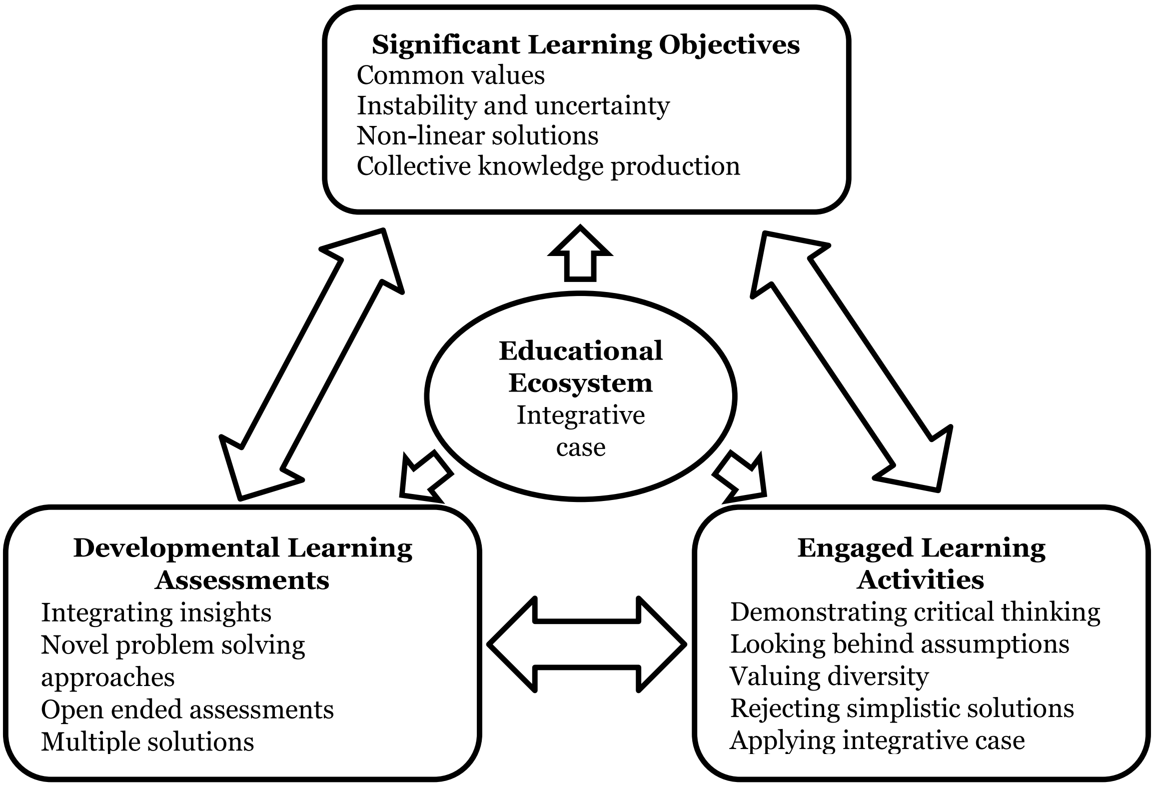

Figure 2: Using Whetten et al.'s Design Elements to Address the Challenges of Supporting Student Learning of Complex Information Infrastructures

5.2 Use Valid Developmental Learning Assessments

In alignment with the CAS characteristics, designing developmental assessments that are motivated by CAS exhibited in the real world context requires a progressive approach from reproduction tasks to complex problem-solving tasks. The overall goal of assessments should be to: 1) support students towards developing skills required to accept and manage uncertainty and the unknown; 2) allow students to learn and apply creative, unorthodox problem-solving approaches; 3) guide the learning process while keeping the results open (adapt to feedback, offer multiple solutions); 4) allow and facilitate work in groups of diverse students who possess different disciplinary knowledge; 5) guide and prompt students to leverage interdisciplinary knowledge; 6) design problem solving tasks that are challenging and require collaborative work; 7) remove the current isolation of each technology presented in separated units of study.

5.3 Select Learning Activities that Foster Active, Engaged Learning

The overall educational experience must be designed so that it also helps to 1) prepare students to understand CAS environments and 2) to address new complex problems after they graduate. More emphasis is needed on learning activities that are clearly associated with the above mentioned expected outcomes. In addition CAS environments require learning activities that are interdisciplinary and integrative. Learning activities therefore must: 1) be designed to expose students to diverse perspectives and encourage them to integrate their insights; 2) be chosen and organised to maximise the chances students will encounter in the future and other relevant complex situations instead of leaving their occurrence to chance; 3) trigger students responses to external stimuli and assess the impact on the CAS, as well as how any change inside the CAS will impact to the environment in which the system resides; 4) guide the learning process while keeping the results open (response to feedback, multiple solutions); 5) reinforce in students the same set of skills and thinking habits across individual subject areas (e.g., value diversity, rejection of simplistic solutions, critical thinking, looking behind assumptions); 6) be organised in such a way to require students identifying connections among individual subject areas, creating common grounds, and integrating disciplinary insights in CAS as a whole.

5.4 Supporting Element: Educational Ecosystem

Key to our approach is the design of an educational ecosystem based on integrative case studies across all three subject areas, containing: 1) rich contextual elements from all three subjects areas based on in-depth comprehensive descriptions that mirror the business context, the complex technologies and information infrastructures identified in each case study; and 2) interdisciplinary problem-based activities focusing on removing the current isolation of each technology being presented in separated units of study. These integrative case studies will be taught using a mix of industry wide technologies such as SAP for ES, ADONIS for BPMS, and ACL for GRC. Students investigating different aspects of the case will first be introduced to hands-on exercises in these technologies, so that their understanding of complex information infrastructures builds upon a foundation of detailed knowledge of the underlying processes and technologies involved. Then, to enhance the active learning experiences, interactive video scenarios will be developed, with each scenario simulating a specific set of business conditions for current problems (e.g., economic, information infrastructure, processes, security, risks, compliance, talent acquisition, geo-political factors, business trends, etc.) and student role playing information. These scenarios will allow students to: 1) explore the problem space using authentic multi-faceted exercises to solve real complex problems faced by organisations, and 2) develop an increasingly agile mindset to engage with the rapidity of change.

6 Conclusion

This paper provides a way for educators to embrace the increasing complexity of the world in which our students live and respond to current challenges faced in BIS education. It acknowledges the problems that arise from silo educational practices and a narrow focus on technical solutions training. It recognises the need for more suitable learning conditions and processes based on principles of interdependency, holism, uncertainty, adaptation and emergence, to enhance and facilitate the learning of the information infrastructures that are encountered in the real world.

This paper makes two main theoretical contributions. The first is the conceptualisation of an information infrastructure as a complex adaptive system as the basis for an educational ecosystem. The second is the extension of Whetten et al.'s (2009) Learning-centred course design to encompass the specific challenges of teaching CAS, and to suggest specific guidelines for learning designs as solutions. In doing so we incorporate a socio-technical dimension to the learning framework to make more visible how learning is enacted by multiple objects, in the context of information infrastructures.

Such an educational approach has significant implications for practice. It has the potential to enable students to develop an increasingly agile mindset, to be open-minded about open-ended solutions, to understand complexity and embrace change, and hence have the employability skills required for an uncertain workplace. This will assist organisations in addressing the impact of rapid technological development, new business and employment models, increasing globalisation and social change on employment and workplace relations.

Despite its limitations as a conceptual piece of work, rather than an empirical validated study, this paper presents a number of future opportunities. Our future work aims to develop and implement an educational ecosystem based on the guidelines presented above, design a suitable evaluation instrument to assess student learning outcome, and refine the adapted learning-centred course design by incorporating the evaluation results.

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