AN INFORMATION SYSTEMS DESIGN THEORY FOR WEB-BASED EDUCATION

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ABSTRACT

An Information Systems Design Theory (ISDT) is a prescriptive theory that offers theory-based principles that can guide practitioners in the design of effective Information Systems and set an agenda for on-going research. This paper introduces the origins of the ISDT concept and describes one ISDT for Web-based Education (WBE). The paper shows how this ISDT has, over the last seven years, produced a WBE Information System that is more inclusive, flexible and is more closely integrated with the needs of its host organization.

KEY WORDS

WBE, Educational Software and Hardware, Best Practices of WBE, Information Systems Design Theory

1. INTRODUCTION

Information Systems (IS) is a field of research concerned with the effective design, delivery, use and impact of information technology in organizations and society [1]. Due to its nature the implementation of Web-based Education (WBE) requires the support of an appropriate Information System (IS). The characteristics of WBE make the design and implementation of an appropriate IS a difficult and time-consuming task that currently has little theoretical guidance. In an attempt to address this problem this paper develops theory-based principles, in the form of an Information Systems Design Theory (ISDT), for WBE.

Information Systems Design Theories (ISDTs), first explicated by Walls et al. [2], are prescriptive theories developed to provide solutions to specialized classes of IS design problems [3]. For practitioners ISDTs are beneficial because they increase development reliability and the likelihood of success by providing principles, derived from kernel theories, that limit the range of system features and development activities to a more manageable set [3]. As a theory the principles generated as part of an ISDT are also open to empirical testing and thus can form a basis for further research.

The development of an ISDT for WBE is important due to the limited nature of theoretical guidance for the design and support of the information systems that support WBE. Theories from education, psychology and related fields have been used to provide guidance for the design of certain features, aspects and applications of WBE (e.g. [4]). However, there has been limited theory-based guidance for the design and support of the underlying information systems.

The contribution of this paper is to offer an ISDT for WBE that has been confirmed through practical application in the development and support of an organizational WBE system since 1996. The resulting WBE system offers a greater variety of features, allows greater flexibility in the choice of applications, and a greater integration within the organization. An ISDT is an important theoretical contribution because it provides guidance to developers and sets an agenda for academic research [3].

The paper starts by offering an introduction to ISDTs, their origins, benefits and components. It then briefly describes the research approach used in this work. The specific ISDT for WBE is introduced through an explanation of its components. Finally, the paper discusses the results of following this ISDT and draws some conclusions about its implications and requirements for future work.

2. ISDTS

Taking a broad view of theory it is possible to identify five inter-related categories of theory based on the primary type of question at the foundation of a research project [5]. These five categories are summarized in Table 1.

Type	Question
Analyzing & Describing	What is?
Understanding	How & Why
Predicting	What will be
Explaining & Predicting	What is, how, why and what will be
Design & Action	How to do something

Table 1
Categories of Theory

ISDTs are an example of theories for design and action. The primary focus of design theory is with general principles that inform practice [5]. Guidance about how to achieve specific goals is intrinsic to a design theory [2]. An ISDT provides theory-based guidance about how to design and support a particular type of Information System.

ISDTs are an integrated prescription consisting of a particular class of user requirements, a type of system solution with distinctive features and a set of effective development practices [3]. Design is both a noun and a verb and consequently Walls et al [2] in defining ISDTs identify components that deal with both the design product (noun) and the design process (verb). Both aspects of an ISDT are informed by kernel theories, either academic or practitioner theory-in-use [6], that enable the formulation of empirically testable predictions relating to the design theory to outcomes [3]. Figure 1 shows the components of an ISDT as described by Walls et al [2].

3. RESEARCH APPROACH

Following the advice of Walls et al [2] the ISDT described here has been constructed through an action research process enabling the iterative development of hypotheses. A similar approach was used by Markus et al [3]. The iterative process commences with a set of requirements and a collection of kernel theories to hypothesize a collection of design and development principles. These principles are used as the basis from which to generate a set of system features that are then implemented and used. Observation of feature use, changing requirements, development of new theory or better understanding of existing theory is then used to revisit and possibly revise the set of design and development principles. At this stage the process can start over. The ultimate aim of this process is the generation of an improved ISDT.

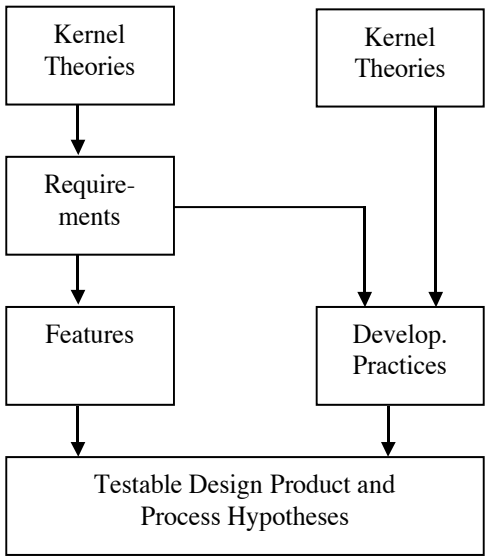

Figure 1
Components of an ISDT [2]

For this work the on-going process has been underway since mid-1996 with the initial design and development [7] of the Webfuse system [8]. Since then Webfuse has been used to support WBE for the Department of Mathematics and Computing at Central Queensland University (CQU) and then the Faculty of Informatics and Communication (Infocom) at CQU. In the last major term of 2002 Infocom had 6820 students, supported by over 299 academic staff, at 12 campuses and via distance education. In that term Webfuse provided course websites for 124 courses including various WBE services including: online assignment submission and management [9], online quizzes, plagiarism detection, online chats, bulletin boards and many others.

4. THE NATURE OF WBE

For most people WBE involves teaching and learning tasks associated with information distribution, communication, and student assessment. However, teaching and learning activities, especially those in WBE, require administrative support in the form of tasks such as assessment management, student enrolments, student tracking, student transfers, payment and a variety of other tasks [10]. The term WBE is used here to encompass educational, administrative and other support tasks that are required for the effective and efficient operation of WBE. This moves WBE beyond the features provided by most commercial Course Management Systems (CMSs).

For various reasons WBE is a task that demonstrates high levels of variability, change and uncertainty. It is these characteristics that contribute most strongly to the formulation of the ISDT for WBE described in this paper. The following paragraphs offer a brief explanation of the importance and source of these characteristics.

The provision of WBE requires contribution from diverse range of potential users including managers,

administrative staff, technical support staff, instructional designers, teachers, students and ad hoc visitors. The variation of the needs, requirements, and tastes of the potential users of WBE means that there is no one correct method for implementing a Web-based course [11]. The ability for teachers to customize an online course to identify their character, personality and teaching commitment can be vital to self-esteem and commitment [12]. Other sources of variety in WBE include: perceived roles, discipline, pedagogy, technology choice, and many others. An online course and the information system that enables it will need to handle change in response to changes in technology, significant differences across disciplines [12], cultural, pedagogical and organizational issues.

Many of the staff (e.g. academics, instructional designers and managers) involved with WBE are knowledge workers. The commitment and motivation of these individuals are a critical success factor in the implementation of WBE IS. Due to the nature of higher education these individuals have considerable autonomy about how they perform tasks and often can and do resist the imposition of new technology and changes to routine.

Web-based Information Systems (WIS), which form the basis for WBE, are different from traditional information systems and require approaches to design and development and are usually a result of grass-roots efforts [13]. Most of the initial applications of Web-based information systems, particularly in Web-based learning, are enacted by lone rangers, individual staff members who are energetic, early adopters of innovations [14].

With little organizational support, these innovative developments are not being appropriated into standard organizational practices [14, 15]. Practitioners often prefer developing a multimedia/online product which is tailor made to their teaching and learning requirements rather than adopting a product developed elsewhere to meet those same objectives [16].

Recent changes in the context and practice of teaching at many institutions can lead to these administrators having significantly different goals and understandings of the teaching situation than the front-line teachers. There is wide recognition that primary practitioners do not place a high value on educational research [17]. Academic practitioners at research universities do not maintain a specialized knowledge of teaching and learning, the emphasis for professional development is placed on their respective discipline areas [18].

Production of the information for WBE requires a high level of expertise from a number of different fields including: content matter, technology, management, instructional design and "web design". Within each of these fields there are often widely variable views on appropriate theory and methods. Between the fields there is often limited understanding or appreciation of the other disparate fields [19]. This lack of appreciation and understanding reduces the effectiveness of many teams attempting to develop online teaching and learning materials.

WBE IS share some of the characteristics of inter-organizational systems (IOS) as they involve a number of groups with different agendas and interests, possibly even groups who feel in competition with each other [20]. IOS are recognized as information systems where the many parties involved magnify traditional problems of politics, management expectations, and to some extent technical concerns, involved [20].

The complexity of teaching and learning on a large scale leads to the development of policies, procedures and support structures to guide the management of teaching and learning activity. Setting up these policies, procedures and support structures usually requires a considerable investment. Not surprisingly, the people within these structures systematically resist attempts to alter their routines and their control over specific tasks [21]. Existing organizational structures and a lack of co-operation often hinders convergent development [19].

The technology enabling the implementation of WBE is changes quickly. New technologies, be they incipient or de facto standards, are being developed every day [22]. Research into new applications of technology such as ubiquitous computing [23] and peer-to-peer offer the potential to drastically change the medium for WBE. As demonstrated by recent licensing changes by vendors of Course Management Systems it is not only the technology that is changing.

5. AN ISDT FOR WBE

This section introduces our ISDT for WBE by describing each of the components (Figure 2) as explicated by Walls et al [2] including: kernel theories, requirements, features, design practices and hypotheses.

5.1. Kernel theories

Hypermedia templates, design patterns, diffusion theory, adopter-based development methodologies and emergent development are the kernel theories for this ISDT.

Hypermedia templates [24] are an approach to simplifying the authoring process while still ensuring the application of good information design principles. Experts, with appropriate skills, are responsible for the creation of hypermedia templates. The use of hypermedia templates enable content experts to take responsibility for maintaining Websites and can thus increase ownership, decrease costs [8] and address the authoring bottleneck problem [25].

Nanard, Nanard and Kahn [26] propose the combination of patterns and templates to enable and simplify the capture and reuse of design. Any general pattern or any

document specific sub-structure used repeatedly is worth being implemented as a template allowing the capture of the corresponding design abstract [26].

Design patterns offer an approach to documenting and supporting the reuse of design which is finding favor in hypermedia [26, 27]. A pattern is a generic approach to solving a particular problem that can be tailored to specific cases. The use of patterns provide a number of benefits including making it easier to reuse successful designs, make proven techniques more accessible to developers, enable choice between alternatives, and improve the documentation and maintenance of existing systems [28]. Hypermedia templates also aid in reuse which is a strategic tool for reducing the cost and improving the quality of hypermedia design and development [26].

Traditional information systems development methodologies are particularly ill suited to emergent organizations. In an emergent organization all features of the organization are continually undergoing social negotiation and consensus building and are never fully formed [29]. The rapid development of technology and global markets contributes to a need for constant change where organizations are no longer stable and must continuously adapt to their shifting environments [29].

Traditional development projects are hard to manage and even harder to change making it difficult to align them with changing organizational reality [30]. Having low-maintenance, stable systems means the organization is continuously battling against its constraining information systems [29].

If an organization and its processes are stable then precisely designed systems can recoup costs. However, if an organization is operating in a continual changing organization the large investment in up front analysis is a poor investment as requirements change before the end of the analysis stage [29]. Additionally the abstract requirements for such systems are often little more than a history lesson in past organizational states or abstractions of obscure user guesswork about future organizational states [29].

Due to the mismatch between emergent organizations and traditional information systems development methodologies, emergent development rejects the goals of traditional information systems development and replaces them with new goals. These goals include [29]: continual analysis, dynamic requirements negotiation, continuous redevelopment, and the ability to adapt.

Many software development methodologies have a developer-based focus. These approaches assumes that a new product will automatically replace inferior products or systems [31]. Developers assume potential adopters will see the benefits just as they see them. In contrast to the developer-based approach, the adopter-based approach focuses on the human, social, and interpersonal aspects of innovation diffusion [31]. Developers are interested in the individual who will ultimately implement the innovation in a practical setting as the primary force for change. The adopter-based theories reject the assumption that superior products will automatically be attractive to potential adopters. They 'seek to understand the social context in which the innovation will be used and the social function the innovation will serve' [31].

Implementing OT&L within an existing organization often involves innovations that are perceived to be complex and incompatible with previous practice. Tornatzkey and Klein [32] found that relative advantage, compatibility and complexity are the most significant factors in explaining relationships across abroad range of innovations. Surry and Farquhar [31] report on a number of studies that confirm the links between relative advantage, complexity and compatibility and the adoption of innovations in education. Attempting to quickly install complex systems that require significant change in practice is likely to fail. Complexity can be created by incrementally assembling simple modules that can operate independently [33]. Evolutionary growth via small, simple steps is liable to be more effective.

5.2. Requirements

An IS supporting WBE will be required to:

- Support the development of a wide range of WBE applications that support the variable and unknown requirements of the many potential users.
- Provide support for ‘lone-ranging’ staff who wish to develop and design their own applications of WBE.
- Be able to appropriate technology, approaches and lessons identified in the literature or learned by ‘lone-ranging’ staff and make it available to other staff.
- Provide services and features that directly solve problems, provide features and are attractive to the broad majority of users who are not ‘lone-rangers’.
- Be able to use information and data from a wide range of sources, formats and information systems.
- Be able to make use of technology from a wide-range of sources, platforms, vendors and deal with on-going changes over time.

5.3. Features

In keeping with the kernel theory of emergent development this ISDT does not make specific recommendations for the type of features that should be provided. Instead it aims to implement a framework through which features appropriate to the context of application can be developed. The propose features of the ISDT for WBE include:

- Structure the system around the concept of hypermedia templates.
- Provide a range of features for the creation, manipulation and modification of templates by the widest possible range of people.

- Where possible hypermedia templates should act as wrappers around existing software in order to reduce the cost of ownership and provide a consistent authoring interface.
- Provide support so that websites can be constructed through the ad hoc, combination of existing templates, the use of site structure defined by a "site template" or without templates at all.

5.4. Development Practices

The following high-level development practices provide high-level principles for the development methodology. In a real-world context more detailed development practices that implement these principles are required. In our experience the methodology offered by extreme Programming [34] has been found to be useful.

- Minimize the distance between the users and the developers. Where possible developers should be users.
- Continuously examine and evaluate the experience of all staff and modify the systems based on the findings.
- Analyze, use and contribute to the literature on WBE.
- Keep analysis, design, requirements generation and documentation to a useful minimum.

5.5. Testable Hypotheses

Drawing on principles from the kernel theories of this ISDT it is possible to pose a range of hypotheses that are open to empirical testing. The following lists some of these and relates them back to the kernel theory on which they are based.

Hypermedia Templates:

- It is possible to construct an IS for WBE around the idea of hypermedia templates.
- An IS for WBE built around hypermedia templates will be more flexible, open and customizable.

Diffusion theory and Emergent development:

- Over time a system built following this ISDT will become customized to the needs and requirements of the particular organization.
- The level of adoption of a system built with this ISDT will be greater than other approaches.

6. DOES IT WORK?

Over seven years of iterative development using this ISDT has provided opportunity to test the ISDT and in particular the hypotheses presented in the previous section. This section briefly discusses the result of the systems use.

The ability to construct a IS for WBE using this ISDT is demonstrated by the existence of Webfuse [8] and its use in the development of WBE for Infocom. The changes that Webfuse has undergone demonstrate its flexibility and customizability. It has used three different Web-based bulletin board systems provided by different vendors. Five different user authentication systems have been used with changes being driven by the available CQU authentication systems. Online assignment submission has undergone multiple generations of development [9]. The implementation of course barometers [35] into Webfuse is an example of the incorporation of an innovation from the literature.

A number of the services provided by or used by Webfuse are unique to its host organization (CQU and Infocom). This includes integration with other CQU information systems including: various authentication and directory services, student records database and timetabling system. In response to staff concerns about plagiarism [9] Webfuse provides copy detection services which are not currently available in any commercial Course Management System. Webfuse provides support for parameterized quiz questions for programming courses.

The incorporation of features that are useful by a majority of staff has contributed to an increasing adoption rate. Table 2 shows how the number of staff using Webfuse has increased since 1999.

Year	# of Users
1999	77
2000	104
2001	297
2002	407

Table 2.
Increase in Staff Adoption of Webfuse

7. CONCLUSION

Drawing on seven years experience implementing and supporting WBE we have presented an Information Systems Design Theory for the design and support of Information Systems intended to support Web-based Education. Such a theory can help both practitioners and researchers. For practitioners it offers theory-based guidance about how to design and implement effective information systems for WBE. For researchers it identifies a number of theory-based principles that are subject to empirical validation. Our experience has shown that use of this ISDT can be used to design and support successful WBE. Use of this ISDT provides an IS underlying WBE that is more flexible, customizable and close to the needs of its specific organization.

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