Software Engineering: Accessing IT Core Concepts

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Abstract

The conceptual complexity of software engineering presents challenges to both teachers and learners. The persistence of these challenges prompted consideration of strategies to enhance accessibility and universal design into courses from the early stages of their development: the responsibility for executing such strategies lies primarily with the Faculty Instructors and Instructional Designers. This Case Study demonstrates how improvements to the accessibility of a software engineering course through development as a fully online course had broader, more comprehensive beneficial effects on the overall teaching and learning process, improving access to the core concepts underpinning IT.

Keywords: software engineering, universal design, accessibility, information systems, instructional design

1. INTRODUCTION

The conceptual complexity of software presents substantial challenges to those who teach: it has been argued that software engineering is one of the most conceptually challenging domains (Hevner et al, 2013). Our increasing dependence on information technology (IT) requires that we maximize access to the core concepts used to design, build and run the systems that support so many aspects of our daily lives.

Recent events highlight the susceptibility of large IT systems to failure as a result of poor design education and understanding (Charette, 2008). Clearly, there is a need for institutions of higher education to address issues surrounding the accessibility of ITs core concepts. As teaching and learning migrate from the face-to-face environment of the classroom to the more virtual settings offered by on-line and blended courses, challenges *and* opportunities emerge. Such migration requires attention, not only to accessibility requirements, but also to accessibility *expectations* and *opportunities* - particularly in regard to online classes and the various aspects of information and instructional technology that support their development and delivery.

The design failures and conceptual challenges that underpin them suggest some shortcomings in the teaching and learning processes. These prompted us to reflect on the strengths and limitations of current practices, guidelines and materials. In turn, that reflection prompts three complementary aims

- To identify gaps and overlaps in the various IT knowledge resources, standards, regulations and guidelines and propose a more cohesive framework more conducive to the development, delivery and assessment

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of courses in both traditional and non-classroom settings;
- To consider the teaching, learning and assessment challenges that emerge as the range of courses delivered in non-classroom settings expands to include those whose learning outcomes are more complex and 'multi-dimensional'
- To articulate a shared design process in which faculty and instructional designers pro-actively explore and exploit opportunities to optimize accessibility for all.

Our experience shows how accessibility can be repositioned: rather than the basis for a 'checklist' of minimum requirements to ensure compliance with IT standards and other regulations, we see accessibility as an agenda. Rather than reacting to shortcomings and limitations and retrospectively addressing the needs of individual students with disabilities, course design can be driven by the opportunity to maximize accessibility for all students, whose abilities to learn these conceptually rich materials span an ever increasing range.

The following section considers the emergence of accessibility issues: the brief review of the literature highlights the universal emphasis on compliance. It also highlights the particular challenges presented by courses that endeavor to teach design. The third section articulates these challenges for a particular course and provides an overview of the institution where the research and design were conducted; the fourth section describes the process that we developed to address these challenges and the penultimate section reports the outcomes of our initiative. The paper concludes with observations and recommendations for further research and development of best practice.

2. PRIOR RESEARCH

In this section we review prior work on accessibility and place it into the context of the teaching and learning challenges and opportunities that on-line course delivery offers. Our review of the literature narrows to focus on the challenges specific to one of the core courses in the undergraduate information systems curriculum (Topi et al, 2010).

Prior research on accessibility has focused primarily on the effects that technological advances in web design have had on accessibility for persons with disabilities. Sloan et al (2002) were commissioned to audit (sic) the accessibility of 11 web sites in the UK higher education sector. The design of this study – an *audit* – is itself revelatory: an *ex post* analysis of impacts that assumes technology to be the 'independent variable'.

The studies by Kim-Rupnow and Burgstahl (2004) and Hackett and Parmanto (2005) place similar emphasis on impacts and outcomes of technology use – a familiar emphasis in the information systems discipline (Bhattacherjee, 2001; Roca et al, 2006). The emphasis on outcomes is reinforced by the research designs that focus on longer-term impacts of the internet and other technologies for students with specific disabilities (Smith and Lind, 2010) and those transitioning into or through further and higher education (Hackett and Parmanto, 2005). The longitudinal emphasis is welcomed, as is the acknowledgement of skills as legitimate and important learning outcome in higher education. However, there is a strong sense of technological determinism: prior research tends to focus either on compliance with standards or regulatory change or on the acceptance of emerging information systems.

It is our contention that 'design' in education is not as universal as Burgstahl and Cory (2008) propose. Accessibility is not just about students with 'disabilities'. Each of us have some limits to our ability when it comes to the rapidly evolving conceptual design challenges that contemporary information systems present (Hevner et al, 2004).

In an era when much emphasis is being placed on Science, Technology, Engineering and Mathematics (STEM) education, it is pertinent to reflect on the centrality and complexity of design in IT. The complexity and conceptual richness of the design artifacts and process central to information systems is particularly evident in the Systems Analysis and Design (SAD) course (Avison and Fitzgerald, 2006; Topi et al, 2010) where students are first introduced to them.

Systems Analysis and Design is the gateway to undergraduate Information Systems programs. The concepts learned here are an essential prerequisite for successful completion of the major: they are also essential for mastery of the language, tools and techniques that enable their effective use in employment (Yourdon, 1993). The primary learning goal is mastery of a range of modeling techniques and their use as the

basis for effective communication between user communities engaged in a particular business and the developers and programmers who build information systems to support the business. The course content is – and always has been - conceptually complex (Avison and Fitzgerald, 2006). This complexity has been compounded by the succession of (traditional) structured analysis and design methods, tools and techniques. The emergence of object-oriented analysis and design methods (Yourdon and Coad, 1991) presents a further cognitive challenge to both teachers and learners.

Object orientation represents a migration of the engineering and mathematics-dominated mind and tool sets that have prevailed since they emerged in the 1970s. Research has shown that structured methods act as a 'comfort blanket' (Fuller and Davis, 2008) and guide the cognitive sense making processes used during analysis and design. Such cognitive inertia can become a potential barrier to learning among both mature (post-experience) students and 'beginning' IS majors. The frames of reference for articulating business requirements provided by structured and object oriented methods are fundamentally different. The more holistic, systems science basis of object oriented techniques provide very different communication 'channels' (Fuller and Davis, 2008) and ways to 'make sense' of business scenarios This, in turn, radically alters the skill set needed to effectively use them.

The specific cognitive mechanisms underpinning sense making are beyond the scope of this paper. Interested readers might care to review the proposals put forward by Hevner et al (2013). However, the process of making sense is pertinent to the design, development and delivery of the Systems Analysis and Design course.

In addition to the concepts underpinning object oriented analysis and design tools and techniques such as Activity Diagrams and Behavioral State Machines, students are also introduced to the industry standard Universal Modeling Language (Rumbaugh et al, 2004) that is used to develop them. UML is taught using industry standard symbol sets and templates in Microsoft's Visio software suite. Thus the 'content' of the course and its learning outcomes comprise a tightly integrated mixture of cognate material and technical skills. The Systems Analysis and Design course is characterized by the 'multi dimensionality' of its learning outcomes.

Early on in the development of the on-line version of the course, accessibility loomed large as a factor critical to the success of the students. Unless they could 'access' the conceptual underpinnings of object orientation, they would be unable to effectively develop and share the various models that comprise the UML. Thus the access challenge is faced by students with a range of abilities, spanning mature, working students with decades of experience with structured methods, students new to the IS discipline as well as those with more specific disabilities.

Wallace (2003) identifies communication and interaction between students and instructors central to coaching the migration of mind and tool sets 'into' object orientation. This point is reinforced in the wide-ranging survey by Collins and van der Wende (2002): instructors who emphasized the delivery of content on-line found that there is 'not much in it' (on-line course delivery) for instructors. The need to coach the development of modeling skills persists, prompting many to abandon efforts to move to on-line and blended instructional methods and giving rise to instructional design inertia.

Such inertia is acknowledged by Kelly et al (2004), who note that the accessibility of e-learning presents additional challenges that may not be faced when providing access to other Web resources. We concur with their arguments that there is a need for a more sophisticated model for addressing e-learning accessibility which takes into account the usability of e-learning, pedagogic issues and student learning styles in addition to the cognitive issues discussed above and technical and resource issues. In the sections that follow we expand on these issues and propose a collaborative, holistic approach to the development of accessible e-learning resources through the application of the Quality Matters Accessibility Standard.

3. RESEARCH SETTING

The University of South Florida St. Petersburg (USFSP) offers a range of distinctive graduate and undergraduate programs in the arts and sciences, business, and education within a close-knit, student-centered learning community that welcomes individuals from the region, state, nation and world. We conduct wide-ranging,

collaborative research to meet society's needs and engage in service projects and partnerships to enhance the university and community's social, economic and intellectual life. As an integral and complementary part of a multi-institutional system, USF St. Petersburg retains a separate identity and mission while contributing to and benefiting from the associations, cooperation, and shared resources of a premier national research university. The university's online learning is delivered through a learning management system; Canvas by Instructure.

1. COURSE DEVELOPMENT PROCESS

Kelly et al (2004) propose a conceptual model that advocates a holistic approach to e-learning accessibility. Figure 1 shows the conceptual structure they propose.

Figure 1 Holistic e-learning accessibility (after Kelly et al, 2004)

Within an encompassing emphasis on quality assurance, a number of course design, delivery and assessment criteria are identified. It is noteworthy that learner needs are central to the model: it is highly 'student centric'. It is also noteworthy that accessibility is given equal weight and prominence to aspects of course design that elsewhere tend to dominate.

Here, accessibility is seen as an equal and integral part of design and delivery as learning outcomes, technology infrastructure, usability and other factors. This multi-dimensional view of quality assurance provided a frame of reference for our efforts to operationalize the model – to balance emphasis on accessibility with other aspects of course design - as we considered the tools, techniques, standards and other guidelines available to us.

As stated previously, we saw a holistic approach to accessibility as an agenda, and so throughout the development process, we considered the elements in Figure 1 concurrently and pro-actively, rather than addressing them one at a time. This highlighted their complementarity and enabled us to develop a course that optimized its conceptual, technological and pedagogic cohesion and accessibility.

Universal Design for Instruction (UDI) is a set of pedagogical principles that operate under the principle that, if you structure the curriculum with the appropriate supports and challenges, all students can learn (Scott et al, 2003) regardless of disability, age, gender, ethnicity, or other characteristics that might affect their learning. Dukes and Scott (2009) and the UDI Online Project at the University of Connecticut outline nine principles for achieving universally designed instruction for online and blended courses.

To better illustrate the UDI applications to the course design, the simple and intuitive principle can be seen in the course and module navigation.

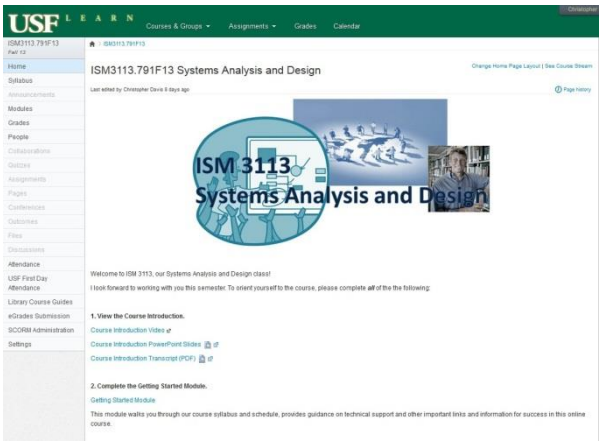

Figure 2 Course landing page

Upon entering the course, students encounter the 'landing' page which provides step-by-step instructions to orient themselves to the course and get started on the material: the left course

navigation menu is reduced to display only the essential navigation options. This page and navigation structure is applied consistently in every course module. This element of our design benefits students who may have learning or processing disorders (visual and auditory); those who could be easily distracted by extraneous information; students who have physical impairments and may be using alternative computer access technologies for navigation, as well as students who have impaired vision and use screen reading technology to navigate the course. In addition to supporting this specific set of students with disabilities, streamlined navigation improves the usability and accessibility of the course for all students.

Another UDI principle incorporated into this course that is of particular importance to the IS discipline was addressed through the inclusion of video and printable tutorials for the software programs required for the completion of practical assignments. Development of these assets allowed us an accessibility enhancement that was not achieved in the previous face-to-face iteration of this course.

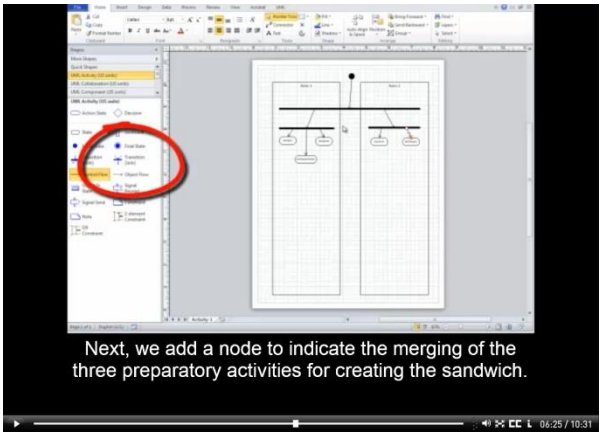

Figure 3 Video tutorial

The inclusion of these tutorial materials meets the principle of tolerance for error. Students have 24/7 access to materials that can be retained and reviewed: the tutorials can be paced as needed so that, if they become stuck at any point in the process of completing the assignment, the student has immediate access to the instructions and visual demonstration. This enhancement has the potential to support students with learning disabilities that need to review information multiple times; it also provides support for students with visual or auditory processing disorders by providing access in video and written formats. It also provides support more universally: experience has shown that these exercises prompt the most questions for students. The conceptual complexity of the UML modeling tools, the modeling software and the concepts that underpin them accentuate the gap between the most and least able students. All have the opportunity to review the tutorial to 'answer' a quick question.

The second set of guidelines encompassed in QM Standard 8 is the WCAG developed by the World Wide Web Consortium. These guidelines strive to enhance technical accessibility to those students using Assistive Technology or needing alternative access to media elements to interact with the course. Following these guidelines makes content accessible to a wider range of people with disabilities and will often make Web content more usable to users in general (W3C, 2008). WCAG follows the POUR model of web design with four guiding principles to make the content Perceivable, Operable, Understandable and Robust.

One example of the WCAG applications within the course is the closed captioning and provision of transcript documents for all course videos. This meets the Perceivability principle to provide alternatives for non-text content and for time based media. Providing closed captions, which allows the students to turn captions on and off depending on preference and need, grants access to students who have hearing impairments, students with auditory processing disorders, and students with learning disabilities to aid in note-taking. It also provides access to students who don't have disabilities, such as a student viewing lectures in a library or in a noisy environment as well as students who speak English as a second language. Providing the transcript document for the videos allows access to a more specific group of students, such as a student who may be deaf-blind and needs to convert the lecture into Braille format.

The idea behind the comprehensive incorporation of these two sets of guidelines is to create a course that is usable and meaningful to all students and, by building accessibility from the early stages in the process, to eliminate the burden on students with disabilities to arrange for accommodation and to the instructors to

modify materials to meet the needs of those accommodations after the fact.

4. SUMMARY

The three examples in this case highlight the substantial benefits of adopting a more holistic view of the course development process and the opportunities that addressing accessibility issues present.

The range and depth of cognate materials in the SAD course - conceptual content of the UML techniques such as Class Diagrams; the complexity of the semantic toolsets used to create the various models and the complexity of the software environment (MS Visio) presents a substantial range of learning outcomes. Figure 1 above highlights that this range generates an equally wide range of accessibility issues.

Those issues can – and should – be seen as both opportunities and challenges. The 'multi-dimensional' learning that characterizes the SAD course presents opportunities and challenges that affect a wider range of students than classes with more traditional learning outcomes that span a narrower range. This is pertinent to both the range of student abilities *and* to their expectations. The learning outcomes for the SAD course require them to do much more than memorize material (Topi et al, 2010). Assessment of the learning outcomes for this course also increase the range of assessment techniques used.

Reflecting on the challenges that we and our students had faced when the course was delivered in a hybrid (blended) format presented us with an opportunity to anticipate and pre-empt those challenges. In turn, that enabled us to explore further opportunities to both improve and widen accessibility. Our experience shows that it is more effective – more cohesive in terms of faculty and instructional designer time and effort – and easier to design with accessibility in mind from the beginning.

The importance of collaboration is a key factor not immediately evident from the work of Kelly et al (2010). In order to bring the model in Figure 1 into 'being', close collaboration was critical to the success of our endeavor. Without close collaboration, the issues raised by the conceptual richness that characterize the SAD course would not have been explored as fully. An open, two-way dialog provided the opportunity for faculty to realize opportunities to adapt materials and process for the wider benefit of all students, rather than merely respond retrospectively to the limited utility of their material for those with specific disabilities. Simultaneously, instructional designers realized opportunities to enrich other courses using media developed to address the complex, 'multi-dimensional' learning outcomes of the SAD course.

Our experience provides useful insight for future course design. Adaptation of existing guidelines such as the QM rubric can provide comprehensive guidance that can be used to initiate changes in both form (instructional media) and practice (course development process). Rather than using them simply as 'check lists' to 'audit' courses, the guidelines can be used to actively bring faculty and instructional designers to a shared awareness of accessibility challenges and opportunities, highlighting their shared responsibilities. Figure 1 clearly infers the need for faculty, instructional designers and administrators to actively collaborate to optimize accessibility at universities.

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