The Dark Side of Digital Transformation: The case of Information Systems Education

Completed Research Paper

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Abstract

This work focuses on the unintended consequences of digital transformation in the context of higher education. We use this familiar context to problematize digital transformation by first discussing the evolution of a required college course over a twenty-year period. We show how increasing digitization under resource constraint lead to a fully online delivery and we highlight three unintended consequences: role reversal, minimization of human interaction, and strategic learning. We then envision an alternative design for an in-class required introductory college course that can scale to large numbers of students under resource constraint. We conceptualize the course as a Socio-Technical (ST) artifact. Framed by intervention theory and recent relevant IS literature, we derive seven meta-requirements and 20 design principles for the implementation of the course.

Keywords: Digital transformation, Socio-Technical artifact, Design Science Research, Information Systems education

Introduction

There is little doubt that digital technology has transformed society as we know it. Over the last few decades, digital innovation was instrumental in creating new products and services, new business models and value creation paradigms. More broadly, it helped transform entire industries (Nambisan et al. 2017; Watson et al. 2017). Technology is generally seen as the driver of modernization and prosperity, playing multiple roles in designing a creative economy. However, digital transformation engenders unintended consequences and risks. Recent examples include cybersecurity threats (Greengard 2016), the spread of

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misleading and false information through social media (Allcott and Gentzkow 2017) and the looming massive displacement of workers through automation (McAfee and Brynjolfsson 2016).

In this paper, we focus on the unintended consequences of digital transformation in the context of required introductory college courses. We use this familiar context to problematize digital transformation and demonstrate the design of an alternative application of technology. We first discuss the evolution of a required course over a twenty-year period. We show how increasing digitization under resource constraint lead to a fully online delivery. We discuss the results of the digital transformation and we highlight its intended and unintended consequences. We then envision an alternative design for an *in-class required introductory college course that can scale to large numbers of students, under resource constraint*. We argue that the design science approach is best suited to our goal because it forces explicit articulation of design principles. We conceptualize the course as a Socio-Technical (ST) artifact (Silver and Markus 2013), substantiated by the interplay of IT, people, processes and organizational structures. Thus, we are not constrained by either an IT-dominant, nor an organization-dominant approach in the design (Sein et al. 2011).

Our design stems from the same need of the previous digital transformation effort: the need to scale an introductory information systems course to prepare more than 1,000 business college freshmen per year. In contrast with the previous approach however, the point of departure for our work is the *centrality of human interactions in learning environments*. Much of the recent attention to digital transformation of education focuses on the use of Virtual Learning Environments (VLE) and Massive Open Online Courses (MOOC). MOOCs and VLEs have proven to be effective and accessible – particularly for students in remote locations (Chatterjee and Nath 2014), students who cannot afford traditional education (Dillahunt et al. 2014), or students who just need to refresh their academic background (Hew and Cheung 2014). Yet, there is a growing consensus in the literature on effective college education that points to human relationships between peers and between the instructor and the students as the catalyst for high-quality college education (Kalay, 2004; Bernard et al., 2009; Gebre, Saroyan and Bracewell, 2014).

In this article, we concentrate our efforts on the elicitation of meta-requirements (Walls et al. 1992) and the derivation of design principles that will guide the implementation of the ST artifact. Thus, we address the first three stages of the design science research process model: Problem identification and motivation, objectives definition for the solution and design of the solution (Peffers et al. 2007). The derivation of meta-requirements is informed by kernel theory and an analysis of the features of technologies currently on the market. Our primary objective is not to provide a critique of the previous course design or to contend that the proposed design is superior – an empirical question we are investigating in our program of research. Rather, we use the juxtaposition of the current and the proposed designs to illustrate how digital transformation is shaped by often implicit choices. We show the value of an alternative approach, grounded in the design science research paradigm, that yields explicit choices substantiated in clear design principles directly stemming from clearly stated goals of the intervention.

Problem Definition

Our work focuses on a standard introductory course in a large business school in the United States of America. The course is titled "Introduction to Management Information Systems" and it is required of all first-year business and economics majors. Its description indicates that the course covers "the role of information technology in business including the development and use of information systems, hardware and software, the strategic impact of IT for businesses and the nature of the IT career." It is also designed to expose students to the use of management information systems to improve managerial decision-making. Over the last five years, an average of 1,563 students per year enrolled in the course, with about two thirds taking it in the Fall semester and one-third enrolling in the Spring.

Historically a second-year course for majors only, in 1994 the department moved it to the first year and the course became a requirement for all college of business students. The personal computers had emerged as a key enabler of knowledge work in the late 1980s and throughout the 1990s. At the time, some of the technical elements of the original course (e.g., database design), were replaced with an introduction to the Microsoft Office suite of productivity tools. As a first-year course, the class had no prerequisite. Following requests from other colleges across campus the department opened enrollment to non-business majors – subject to space availability. Mirroring the widespread adoption of IT and the success of the personal computer, course enrollment grew steadily almost every year. The course was later split (2009) and given two separate course numbers, one for the required class for business majors, and one for the elective class available to non-business majors (Table 1).

Table 1: Enrollment by Major by Year

	All Majors					
Year	Enrollment	Sections	Session Size			
1997	1377	33	41.7			
1998	1854	44	42.1			
1999	1924	46	41.8			
2000	2029	47	43.2			
2001	2457	39	63.0			
2002	2454	29	84.6			
2003	2368	25	94.7			
2004	2791	29	96.2			
2005	3469	37	93.8			
2006	3208	30	106.9			
2007	2977	32	93.0			
2008	2586	15	172.4			
	Non-Business Majors			Business Majors		
	Enrollment	Sections	Session Size	Enrollment	Sections	Session Size
2009	1249	5	249.8	1117	18	62.1
2010	1206	5	241.2	1140	17	67.1
2011	1156	5	231.2	1319	14	94.2
2012	1463	6	243.8	1513	15	100.9
2013	1660	6	276.7	1499	11	136.3
2014	1848	6	308.0	1525	12	127.1
2015	1289	4	322.3	1612	9	179.1
2016	1265	6	210.8	1666	9	185.1

Traditional Approach

In the mid 1990s, the pedagogical approach was dictated by the state of the art at the time. Personal computer penetration in households in the US was only 22.8% in 1993 and 36.6% in 1997 (Cheeseman Day et al. 2005). Thus, instructors held class in a state of the art computer lab, equipped with 48 computers. They started each session by briefly introducing the skills that would be covered then provided students with standard practice assignments and progressed through the solution, showing the work on the in-class projector (Piccoli et al. 2001). In this approach, still in use in many schools, practice assignments provided the platform for discussion of issues arising during the completion of the work such as efficiency tips (e.g., shortcuts), alternative solutions and common mistakes. The inevitable difficulties encountered by students provided opportunities for “teaching moments” and the instructor decided whether to use the question to highlight a common problem or rapidly move on and address the issue individually with the student after class.

On their own time, the students completed homework assignments. These projects mirrored the in-class practices and provided the context for students to independently exercise the skills they had acquired. Two teaching assistants (TA), each assigned 10 hours a week, held office hours in the computer lab. The TAs did not cover material but had deep familiarity with the homework assignments and were on call to help students while they were completing their work. Students who owned a home computer could work independently and visit the lab only when they had questions. For many students, the lab was equivalent to a peer study group. Some students would complete the homework together while others developed a routine of working during the TAs office hours. Some instructors also held their office hours in the lab. For those students without a home computer, the lab was the only place to work and this limitation of flexibility seemed to encourage the development of a valued community of learners.

The relatively low student-teacher ratio and the ability to teach face-to-face fostered the personal relationships between students and instructors. The department drew heavily on its PhD and Masters programs for qualified teachers and tutors. This approach enabled the department to staff the course, which peaked in 2000 at 47 sections for the year (see Table 1).

Piloting the Virtual Learning Environment

In the Fall of 1998, the department began to investigate the online delivery of the course (Ahmad et al. 1998; Piccoli et al. 2000). Using an experimental design that balanced instructor and learning model, the pilot included four sections of the course – two using the traditional in-class pedagogy and the other two delivered via the Internet. A total of 192 students started the experiment. Those assigned to the VLE only attended class for an introductory session on the first day and for examinations (Ahmad et al. 1998).

The VLE was a custom designed online course grounded in the same learning theory used for the in-class sections. The content was organized in learning modules mapping directly to the skills needed to complete the practice assignments, including visual animations (Ahmad et al. 1998). The VLE organized skills in menus with relevant cross-links for direct access to specific modules. Using HTML and JavaScript to automatically resize windows the pedagogical content could be displayed on the screen along with the software application in which the students would be practicing (e.g., Excel). Thus, mirroring the in-class workflow students in the VLE learned and practiced skills simultaneously. Communication with the instructors and amongst students occurred through an online asynchronous public forum with threaded discussion (Piccoli et al. 2001).

At the completion of the pilot, usable data was available for 74.4% of students online and 87.3% of students in the traditional classrooms. For those completing the course online, the results showed that they performed equally well on course mastery to the in-class students, but reported significantly lower satisfaction with the learning experience and significantly higher computer self-efficacy (Piccoli et al. 2001). In the Fall of 2000, the department repeated the pilot with 215 students enrolled in four online sections. This second trial was not designed to compare the VLE to a traditional in-class delivery, but rather to evaluate the scalability of the VLE. It also led to an investigation of the impact of prior knowledge, Internet use, and computer self-efficacy on learning outcomes and motivation to learn in a virtual learning environment (Simmering et al. 2009). Assessing the logistics of moving all sections to a VLE, the department investigated commercial software to replace the custom developed system used in the original pilot. One of the advantages offered by these applications was automatic grading of students' homework and exams, a feature that eliminated the primary obstacle to scaling the size of the sections beyond 48 students. As the department experimented with more sections and introduced commercial software, the focus of the class drifted almost exclusively toward practical skills and the Microsoft Office suite, with foundation IT concepts increasingly marginalized in the curriculum.

Scaling the Virtual Learning Environment

As demand for the course continued to grow from other colleges, in 2008 the department split the course into two versions: one for business school students and one for outside students. Encouraged by the success of the online learning initiatives and by the emergence of multiple vendors of "course solutions" focused on Microsoft Office competency[2] the department committed to a fully online delivery of the course for all sections. Resource constraint, rather than pedagogical superiority, was the primary driver of this decision. The university suffered repeated budget cuts and the masters and PhD programs that graduated a combined 21 students in 2000 had shrunk to 3 graduates in 2008. The increase in class size for the first-year course was considered inevitable. After some experimentation, the department settled on a major vendor system with the following features:

- Online Books: All content is delivered online, no downloads required.
- Virtual Microsoft Office environment: No software installation required, a simulated application runs in the Web browser allowing students to practice specific skills.

[2] Large publishers such as McGraw-Hill Education (SIMnet), Cengage (SAM), Prentice Hall (Train & Assess IT) and Pearson (MyIT Lab) began entering the market in 1999.

- Assignments: The instructor assigns specific skills for the students to practice as graded homework.
- Gradebook: Assignments are automatically graded and the instructor receives a standardized report.
- Search: Through search, users can navigate directly to content referring to a specific skill.
- Videos and interactive "Guide Me" pages: Screen capture videos that demonstrate how to complete individual skills.

The application automatically grades the work students performed in the simulated environment. It also has the ability to evaluate "projects" – structured assignments the student completed using the actual software application (e.g., Excel). Finally, the course solution tracks student activity and provides instructors with access to very specific reports of individual students' usage. The courses do not have a physical classroom assigned since students and instructors never meet face to face.

Outcomes of Digital Transformation

In this section, we present results from our analysis of the department experience. These results are based on multiple interviews with the professor who chaired the department from 1994 to 2015, the lead instructor for the freshmen course from 1998 to 2017, three current instructors, and three current students. We also engaged in observation of assignments completion by the students. However, we stress that our aim in this analysis is to ground our problem definition in actual experience, rather than provide a rigorous case analysis of the department's experience.

Efficiency

From the standpoint of an academic department, efficiency in the context of an introductory college course is defined as student throughput per section. Historically the size of the computer lab and the ability of the instructor to grade homework assignments determined size limits for the in-class version of the course. Conversely, the maximum number of students in the online course is not subject to the same restrictions and fluctuated over time around 200-220 students per section, peaking at 325 in times of need. We compute efficiency gains by figuring the number of sections the department would have to staff under the physical restrictions of 48 students per section, versus the actual number of sections staffed each year (see Table 1). To simplify the analysis, we limit our focus to direct costs of human resources (about $10,000 per section on average). Despite being a conservative estimate not including indirect cost (e.g., maintaining and staffing the computer labs, utilities, and the like), the project yielded impressive cost savings and efficiency gains. Specifically, the department generated average savings of $426,510 per year for a total of $5,501,042 between 2001 and 2016.

Effectiveness

Effectiveness in college courses is measured as learning outcomes and satisfaction with the learning experience (Piccoli et al. 2001). A precise analysis of effectiveness is not possible in our case. However, the individuals interviewed, both instructors and students, pointed to the trade-off entailed by the VLE. Administrators and instructors involved in the course lamented the limitations of the approach readily suggesting that an in-class delivery "is better," but basically impossible with 220 students per section. Among the positive aspects of the in-class delivery they mention: the ability to illustrate particularly difficult concepts, the ability to respond to questions in real time, as they arise, the ability to convey tacit knowledge (e.g., tips and tricks) that improve students' efficiency and effectiveness and the ability to assign more meaningful homework and projects. The instructors also pointed to the inherent limitations of using a simulated software environment rather than having students practice directly in the software using their own computers. This limitation was echoed by the students we interviewed who focused specifically on Microsoft Excel. While there are many opportunities to use the software in other courses in the business school curriculum, the students suggested that they rarely think about Excel as an option in the following courses – unless required to do so. This is a surprising outcome since *Introduction to Management Information Systems* is a prerequisite for second-year courses in statistics, accounting and finance – subjects where the proficient use of Microsoft Excel would create efficiencies for the students completing assignments. When pressed for an explanation of their behavior the students indicated that they don't feel comfortable enough to use the software in those courses. This outcome is not surprising however as gaining comfort with software applications is a function of time on task and actual use of the application (Gardner et al. 1993).

Unintended Consequences

While efficiency and effectiveness were the *intended* consequences of the digital transformation of the course by the department, we extended our analysis to investigate the "full complement of consequences, intended *and otherwise*, of deploying and employing ST artifacts" (Silver and Markus 2013, p. 84). We identified three negative unintended consequence of the implementation of the online course: role reversal, minimization of human interaction, and strategic learning.

Role reversal occurs when two individuals or entities exchange their duties or positions. We characterize this effect as the "digitization of the professor" whereby the "course solution" starts assisting the instructor with administrative tasks, but over time disrupts the role of the teacher and takes over fundamental activities. In a traditional college course the instructors engage in content and pedagogy decisions that define the course and its level of quality. These decisions are typically subject matter dependent. They include:

1. Identification of the content that should be covered.
2. Selection of course material and content development to cover any gaps in available sources.
3. Identification of the optimal content delivery approaches (i.e., pedagogy) and their implementation both in class and outside (e.g., labs, office hours).
4. Taking pedagogical decisions about how to test mastery of the content and developing the testing instruments (i.e., assignments).
5. Establishing the rules for the course (e.g., tardiness and attendance policy) that foster the appropriate learning environment.

Course delivery also entails a set of necessary administrative and support activities. These activities are similar in all courses and largely independent of the subject matter. They include:

1. Administering exams.
2. Validating excuses for missing required assignments.
3. Answering procedural emails (e.g., "will this be on the exam?").
4. Computing and communicating grades.

In the physical classrooms, professors are entrusted with content and pedagogy decisions, while support activities can be outsourced to teaching assistants or administrators under their guidance. As the department gravitated increasingly toward the VLE seeking the efficiencies provided by the online delivery, control of both the content and the pedagogy shifted to the digital "course solution." Early on, this was substantiated in the increasing prominence of practical skills (e.g., Microsoft Office) over the theoretical concepts listed in the course description. Later it manifested itself in shifting the bulk of learning activities to the simulated online environment and simulated homework assignments. In other words, control of both content and pedagogy had shifted to the VLE with the instructors relegated to course administration and support.

Note that instructors have used outside materials (e.g., textbooks) well before the digital transformation of courses. However, in this case, the instructors still need to deliver the course. Thus, they must prepare for class, be ready to answer questions, engage with students, monitor whether they are following along or they become disengaged. When the department embraced a digital transformation approach that included digitization of course delivery, the relationship between students and instructor changed, leading to the minimization of human interaction. The instructors interviewed estimated that only 3-5% of students would ever interact with them face to face over the course of the semester. All other interaction would happen through emails, with an estimated 40-50% of the students sending at least one email over the course of the semester. This means that about half of the student population never communicated with the teacher, either physically or electronically. Moreover, the overwhelming majority of these emails refer to procedural and administrative matters, with only an estimated 15% being about the course content. While these results are not systematic or generalizable, they conform to a "technology-shaping perspective" (Markus 2005) showing how even small differences in ST artifact design lead to significant differences in the pattern of use over time (Palen and Grudin 2003). In our case, having digitally transformed the content and course delivery, the department encouraged a pattern of use that led students to rely exclusively on the system to master the course objectives. This outcome stands in sharp contrast to the community of learners that had emerged around the completion of homework in the computer lab when the course was held in class and most students did not have a home computer. The minimization of human interaction was not a stated objective of the digital transformation, and instructors remained available for regular office hours. But this availability was largely perceived as nominal, and the pattern of use that emerged shows the difficulty in digitizing important elements of the traditional pedagogy: the ability of instructors to leverage serendipitous "teaching moments" that emerge while students are completing the practice assignments and the development of a learning community.

The lack of human interaction also appeared to foster strategic learning. Strategic learning occurs when students focus "primarily on doing well in school, avoiding any challenges that will harm their academic performance and record" (Bain 2004, p. 34). The "course solution" sales representative suggested in an early meeting that "if you don't assign points to [the homework], [the students] just won't do it." When asked about this comment, instructors tended to agree, and all teachers in each section of the course used weekly automatically graded assignments to motivate students. While strategic learning is by no means an exclusive occurrence in VLEs, it can be exacerbated when performance goals are set based on extrinsic motivators (e.g., the grade) rather than a mastery orientation. The literature has long recognized and corroborated the notion that extrinsic motivation depresses intrinsic motivation (Deci 1971). Effective instructors combating strategic learning in college courses promote intrinsic motivation by linking course content to students' interests (Bain 2004). The students we interviewed mentioned that working in isolation in the VLE they focused on completing the assignments as directed by "the system" while carefully monitoring deadlines. Despite all having received the highest mark in the course none of the students we interviewed spoke about the importance of becoming proficient IT users during our discussions. Strategic learning is not unique to VLEs and we cannot generalize from our limited observations. However, we argue that having removed any human interaction and having shifted the locus of causality (deCharms and Shea 1976) of student behavior to the VLE, it was natural for the students to become strategic learners, and focus on the grade as the principal outcome of their learning experience in the course.

In summary, the above historical case analysis suggests that the digital transformation of the required introductory college course we studied, fostered significant efficiencies while engendering unintended consequences. In other words, while creating much needed efficiencies, the digital transformation effort had an unforeseen "dark side." In the remainder of this paper we investigate a competing design that uses technology to fulfill the need to scale an introductory information systems course under resource constraint. However, mindful of the unintended consequences of the VLE currently in use, this approach takes as its point of departure the centrality of human relationships within the learning community (students, instructor and support staff).

Digital Transformation Enabling Human Interaction

We propose that, rather than "digitizing the professor," the deployment of digital technology should enable instructors to maximize the time they can devote to meaningful engagement with the students – in and outside of class. We follow a design science approach as we seek to uncover the design principles for an ST artifact to foster students' commitment to the learning process. Our goal is to design a high-quality in-class required introductory college course that can scale to large numbers of students under resource constraint. In this article, we limit our attention to the elicitation of meta-requirements (Walls et al. 1992) and the derivation of design principles that will guide the design of the ST artifact (Silver and Markus 2013) enabling our intervention. The derivation of meta-requirements is informed by a theoretical framework (i.e., kernel theory) and an analysis of the features of technologies currently on the market.

Theoretical Framework

Conceptualizing a semester long college course is an act of design – "engineering an environment in which [students] learn" (Bain 2004, p. 49). It addresses the three main elements of the learning experience: learning activities, outside of class student behavior, support and administrative activities. The first element is concerned with ensuring that appropriate content is covered and that students are engaged with it. The second element is concerned with the activities that the learners perform on their own time, when they engage with the material to master both concepts and skills. The third element is concerned with the management and completion of all support activities that don't directly influence students learning, but are nonetheless necessary to the functioning of the class (e.g., scheduling exams, grading). These three elements of design are particularly critical in large classes under resource constraint because the sheer number of students puts pressure on quality delivery. In a large course, it is harder to engage the audience in class. It is more difficult to keep track of their progress and behaviors (e.g., attendance, use of course resources) and to reach out to them when they fall behind. It is more time consuming to provide timely feedback and to administer the course.

Information technology has always played an important role in course design (e.g., clay tablets in ancient Rome, textbooks and computer simulations in the modern classroom). Over the last two decades, with the widespread adoption of personal computer and the Internet by faculty and students alike, IT has been used, more or less aggressively, to enable each phase of college course implementation. In the first phase, the impact of IT ranges from course delivery in VLEs without any face-to-face interaction as the one described in our case analysis, to traditional classrooms augmented by clickers (Moss and Crowley 2011) or interactive mobile apps (Gan and Balakrishnan 2017). In the second phase, the impact of IT ranges from the use of Learning Management Systems (LMS) supporting students' activities outside of class, to learning analytics and predictive modeling designed to identify students at-risk of failing (Jayaprakash et al. 2014). In the third phase, course management, IT enables efficient grade management, online testing and, in some cases, automatic grading of assignments (Pellet and Chevalier 2014).

Intervention Theory

In *Intervention Theory and Method*, Chris Argyris posits that "to intervene is to enter in an ongoing system of relationships [...] An intervenor, in this view, assists a system to become more effective in problem solving, decision making and decision implementation in such a way that the system can continue to be increasingly effective in these activities and have a decreasing need for the intervenor" (Argyris 1970, p. 15). Intervention theory is concerned with the general process of interventions that increase the effectiveness of a system, and it has been applied in diverse fields at both the individual and organizational level. Three principles guide the design of interventions: leveraging valid and useful information, allowing free informed choice by the client, and fostering internal commitment.

Intervention theory posits that the prerequisite to any intervention is the availability of valid and useful information. Valid information is that which can be publicly verified and shown to affect the phenomena the intervenor is seeking to affect. Useful information is that which the client would be able to use to "control their destiny" (Argyris 1970). For example, while a person's genetic make-up will reliably predispose them for some illness or diagnosis (e.g., diabetes), there is little the individual can do to avoid the illness based on knowledge of their genetic predispositions. Conversely, eating habits and exercise information, would be both valid and useful. Like genetic make-up, they have been reliably shown to affect the propensity toward the disease (i.e., valid information) but the client can also turn the knowledge of her habits into action to influence the outcome (e.g., increase exercise, modify the diet). A similar parallel in college courses can be drawn with respect to natural aptitude and study habits. The former may be shown to be a valid predictor of learning in the course, while only the latter is both valid and useful.

Free informed choice points to the centrality of the client system in the implementation of the intervention – and therefore in its design. It is free choice that enables the client to be "self-responsible" - to take ownership for the activities required to achieve the goal. This principle is particularly important in situations where internal commitment is critical to the success of the intervention, such as those in the human and social sphere (Argyris 1970). For example, while free and informed choice is of marginal import to an invasive surgery intervention (e.g., appendectomy under full anesthesia), it is necessary to the success of an intervention designed to help a smoker permanently quit the habit.

Internal commitment refers to the degree of ownership and responsibility the client feels with respect to the intervention. In other words, when internal commitment is high, individuals act purposefully on the choices made because they trigger their own sense of responsibility. Returning to the example of the smoker, a person that has decided to permanently quit the habit because of the birth of a child (e.g., high internal commitment) is most likely resolute in their action having internalized a high degree of ownership for the results of the intervention. The power of internal commitment comes from the belief of control individuals have over their action and the outcome, as well as the sense of purpose for the initiative. Having processed valid information and having taken a free and informed decision, rather than reacting to external rewards or induced behaviors, the client is likely to act as needed to reach the goals (Argyris 1970).

The three principles of intervention theory are interdependent. The availability of valid and useful information is necessary for the client to make decisions that are free and informed. At the same time, the outcome of these decisions provides information that contributes to the stock of valid and useful information available to the client and the intervenor. Moreover, to the extent that the results of choices being made by the client are positive, those choices strengthen internal commitment.

In the remainder of this section, we map recent information systems literature to the three principles underlying intervention theory to develop meta-requirements and design principles grounded in recent relevant literature. Specifically, we focus on digital data streaming as a source of valid information, learning analytics as the basis for free and informed choice, and persuasive technology as the IT enabler of internal commitment.

Meta-Requirements and Design Principles Discovery

Given our focus on ST artifacts (Silver and Markus 2013), the proposed meta-requirements for system design do not pertain only to the technology and software deployed in the course. Rather they include both IT-dominant and organization-dominant elements (Sein et al. 2011). We organize the meta-requirements along the three principles of intervention theory. For each one, we list specific design principles derived from relevant literature.

Valid Information through Digital Data Streaming

Since the introduction of computers in business and organizations, information systems theorists have recognized the potential of information technology to create digital representations of processes and activities. As Mark Weiser, who coined the term ubiquitous computing put it: "the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it" (Weiser 1991, p. 94). Recent information systems literature points to experiential computing as the field concerned with the computer mediation of everyday activities (Yoo 2010). As computing functionalities become increasingly embedded in everyday objects with the widespread adoption of smartphones (Humphreys et al. 2013) and the development of the internet of things (Ives et al. 2016) digital technology mediates the four dimensions of the human experience: time, space, actors, and artifacts (Yoo 2010).

Table 2: Elements of a digital data stream segment (source: Pigni et al. 2016)

Element	Description	Example
When	The time when the data segment was created	A timestamp with date, time, and time zone
Where	The location of the entity when the segment was created	Latitude, longitude, elevation
Who	The unique identifier of the entity that caused the data segment to be created	Person's customer number, RFID of a pallet, URL of a web site
What	The activity that caused the segment to be created	The identifier of an item in a sales transaction, the arrival of a ship in a port
How	The means by which the event was initiated, authorized or completed	Credit card number for payment, status of arriving flight (e.g., safe landing)
Why	Motivation for the action related to data segment creation	Birthday gift, planned destination

The computer mediation of everyday activities generates digital representations of events at their inception, a phenomenon known in the literature as digital data genesis (Piccoli and Watson 2008). For example, when a customer searches for availability on Delta.com a record of that event, in digital format, is immediately created. When a student swipes her ID at the gate of the university gym, the scanner generates a digital record of her presence at the gym. Upon digital data genesis events take on the characteristic of digital goods: nonphysical, durable, with negligible reproduction and distribution cost, with infinite replicability and customizability, and non-rivalry in consumption (Bhattacharjee et al. 2011). Often these digital data are ephemeral and they are erased or aggregated. Increasingly, however, they become part of a Digital Data Stream (DDS). A DDS is a "continuous digital encoding and transmission of data describing a related class of events" (Pigni et al. 2016, p. 7). In other words, a DDS channels the digital representation of a class of events at their inception and makes them available for harvesting by organizations (Piccoli and Pigni 2013). DDS are generated by human behavior (e.g., a Tweet, a Google search) or by machines (e.g., a CO2 reading from a weather station, a picture by a speed camera). They capture up to six primitives describing the event (see Table 2), and these elements form the basis for event mining (Xie et al. 2008) and ontology development (Ding et al. 2010). In some instances, the DDS is available as a byproduct of existing systems, in others the firm consciously generates it by deploying the needed technology. In either case, DDS can serve as "seed innovations" to start the digital transformation of long established industries (Watson et al. 2017) and, more simply, they can be important sources of valid and useful information.

Intervention theory posits that interventions must be based on valid and useful information. Information is valid when it is shown to affect the outcome while being independent of it. For this reason, the digital transformation of an introductory college course should focus on tapping into, or generating, the DDS that yield the needed valid and useful data. This meta-requirement calls for the proactive design of real-time data collection of students' behaviors. We argue that DDS, with their focus on real-time digital data genesis and real-time availability of the stream for action, are the optimal framework for generating valid and useful data.

MR1: The ST artifact supporting large introductory college courses should record all students' behaviors.

- DP1.1: Generate an attendance DDS for all physical activities (e.g., class session, lab sessions).
- DP1.2: Generate a resources utilization DDS for required and optional resources (e.g., readings, practices).
- DP1.3: Generate a completion and performance DDS for required and optional assignments.
- DP1.4: Generate an interaction DDS for tracking communication.

Free and Informed Choice through Learning Analytics

Perhaps the most evident application of DDS in the digital transformation of education has been in learning analytics. The advent of LMS, such as Moodle or Blackboard, enables the digital data genesis of student activities in and outside of the class. Modern LMS track such variables as login frequency, time spent on the system, download of materials and resources, completion of exercises, communication and the like (Mwalumbwe and Mtebe 2017). It is this ready availability of digital data that spurred the development of academic analytics (Campbell et al. 2007), an area of inquiry focused on the measurement of learning outcomes to increase accountability of educational institutions (Arnold 2010). While early academic analytics comprised the analysis of student's performance both over their career (e.g., graduation rates) and in individual course learning outcomes, the two are now separate areas of inquiry. Academic analytics continues to refer to the aggregate examination of students' attainment and academic career performance, while learning analytics focuses on "the use of analytic techniques to help target instructional, curricular, and support resources to support the achievement of specific learning goals" (Van Barneveld et al. 2012, p. 8).

Early works in learning analytics focus on measuring effective usage of the LMS, as well as the extent to which different LMS usage patterns impact student performance (Mödritscher et al. 2013). The research suggests that the cumulative time connected to the LMS and the regularity of logins, together with interaction with peers and number of resource downloads are significant predictors of the final grade (Kotsiantis et al. 2013; Yu and Jo 2014). While the direction of causality in these studies is not clear, the work suggests that patterns of use and time on task correlate with performance in the course. In support of educators and administrators, learning analytics provides predictive models and visual support, in the form of dashboards (Macfadyen and Dawson 2010). However, reporting and visualization functionality of these built-in analytics tends to be limited and, consequently, faculty tend not to use them and students have no access to them (Ferguson 2012).

While the above review suggests that learning analytics has focused on administrators and it has been reactive in nature, there are important recent works more closely aligned with the tenets of intervention theory (Jayaprakash et al. 2014). This research recognizes that students often don't realize how well they are performing until it is too late to course-correct (Pistilli and Arnold 2010). For example, recent work shows that simple interventions such as alert emails that spur faculty-student interactions lead to better retention rates (Tinto 2012). In an implementation of an early alert system, a simple email notification was used to alert the student of their at-risk status as computed by a predictive model. The authors reported that 55% of high risk students receiving the alert moved to the moderate risk category and about 25% moved to the low risk or even the no risk category by the next measurement. Of those who were originally classified as a moderate risk, almost 70% moved to the low or no risk categories after the email intervention. In line with the results advocated by intervention theory, notification interventions spurred recipients to continue to seek support at a rate 30% higher than the control group *even after* the alerts stopped (Arnold 2010). More recent work reports on the development and implementation of an open source academic alert system, which leveraged data from an open source LMS (Jayaprakash et al. 2014). The system was designed to be general, rather than specific to a single course, and to be able to scale across institutions. Thus, the authors relied on readily available DDS and could not capture some critical sources of predictive data such as absenteeism and ongoing performance (e.g., homework proficiency). However, they introduced and tested an early alert system for at-risk students. In various introductory courses (e.g., math, sciences, business, art) at four different institutions alert interventions were benchmarked against no intervention using an experimental design. Running a predictive model after 25%, 50% and 75% of the time in the course had elapsed, investigators identified at-risk students and sent an email alert suggesting two types of corrective actions. Using the final course grade as the outcome variable, the study demonstrated that the alert, regardless of the corrective action indicated, had a significant positive impact. In other words, raising student's awareness about their risk of failing significantly reduced the chances of actual failure (Jayaprakash et al. 2014).

Early findings and applications show the promise of digital transformations based on intervention theory. However, there has been very little attention directed at the designs of early warning systems for making college students in required courses self-responsible. For example, while intuitively earlier intervention is better (Newman-Ford et al. 2008), intervention theory would suggest that enough data must be available for the intervention to be based on valid and useful information (Argyris 1970). Beyond timing, no research we are aware of has investigated the optimal frequency of intervention, the DDS with greatest impact, the appropriate technology channel for the intervention, the appropriate blend of technology and human interaction in yielding behavioral change.

The second principle of intervention theory is free and informed choice, placing the locus of decision making on students once they are armed with valid and useful information. Free and informed choice in college level courses has been shown as a trait of effective teachers who "avoid using grades to persuade students to study" (Bain 2004, p. 36). They instead carefully motivate the importance of the learning occurring in the course by making explicit the "payoff" associated with mastering the learning goals and deliberately giving the students a sense of control over their learning outcomes (Bain 2004).

MR2: The ST artifact supporting large introductory college courses must not conflate behavior with learning

- DP2.1: Activities tracked through DDS have no bearing on the student's learning assessment (i.e., the grade).
- DP2.2: Assignments and homework are a service to students and have no bearing on the student's learning assessment.
- DP2.3: Learning assessment is measured, independently of student behavior, through dedicated ad-hoc evaluations (i.e. exams).

It is possible that students will not readily understand, or buy into, the notion of free and informed choice. This is because it is unlikely that free and informed choice has been the norm in their schooling and in concurrent courses. It is therefore necessary that the ST artifact couple technology design functionalities with organizational interventions that reinforce it. Designing the course to decouple behaviors from outcomes (MR2) aims at eliminating external incentives for counterproductive behaviors (e.g., coming to class only to accrue "participation" points, cheating on homework, or engaging in strategic learning). It also fosters learner control, the ability of students to "make their own decisions regarding some aspects of the path, flow, or events of instruction" (Williams 1996, p. 957).

MR3: The ST artifact supporting large introductory college courses treats students as self-responsible units and maximizes learner control

- DP3.1: Regular homework and practice assignments are available to students.
- DP3.2: Evaluations and feedback are provided for any assignment students voluntarily submit.
- DP3.3: Assignments are designed to be automatically evaluated and students are directed to physical interactions (e.g., lab hours)[3] to discuss the results if clarification is needed.

An important tenet of intervention theory is that free choice must be informed choice, based on valid and useful information. The research on learner control corroborates the importance of informed self-assessment. Students vary in their ability to make appropriate educational decisions to take advantage of learner control (Reeves 1993) and generally tend to overestimate their ability without a feedback loop (Lee and Wong 1989). Learning analytics research has shown that, with access to ever more comprehensive DDS (MR1), it is possible to reliably classify students at-risk. However, this predictive data is rarely made systematically available to students themselves (Jayaprakash et al. 2014). We posit that students should have accurate real-time visibility of their own behaviors.

MR4: The ST artifact supporting large introductory college courses exposes all behavioral and performance data as soon as it becomes available

- DP4.1: Provide a dashboard for visualizing students' individual behavior and performance.
- DP4.2: Apply learning analytics techniques to identify and alert at-risk students.

MR5: The ST artifact supporting large introductory college courses contextualize behavioral and performance data for students.

- DP5.1: Provide a dashboard for visualizing anonymized aggregated current student cohort behavior and performance
- DP5.2: Provide a dashboard for visualizing anonymized behavior and performance by previous student cohorts.

Internal Commitment through Persuasive Technology

Designing technology for maximum influence is the realm of the emerging field of persuasive technology. Persuasion is an inseparable element of human communication in which one party tries to change the other party's "mental states" (O'Keefe 2004), their beliefs, attitudes and behavioral intentions (Fishbein and Ajzen 1977, 2011). Over the years, research investigated the mechanisms of persuasion: the behavioral change from cognitive responses to a persuasive stimulus (Greenwald 1968). Depending on individual's involvement or cognitive capabilities one may leverage the different cues of persuasion (Chaiken 1980; Petty and Cacioppo 1986) like the quality of a message (Petty and Cacioppo 1984) or the credibility of a communicator (Hovland and Weiss 1951). Another important element of persuasion is the receiver's emotions as they influence perception and mediate the message (Dillard and Peck 2001). Thus, the success of persuasive communication depends on matching the persuasive message with individual attitudes and tailoring it to a particular receiver (Hullett and Boster 2001).

The computer mediation of everyday activities (Yoo 2010) elevated the role of IT to that of a potential agent of persuasion, not just a mediator in person-to-person interactions (Nass 2010). Persuasive technology, defined as "any interactive computing system designed to change people's attitudes or behaviors" (Fogg 2003, p. 1), can therefore be an agent of influence (Nass 2010) by delivering persuasive stimuli (Fogg 2009a) designed to influence the recipients to form, reinforce or change their attitudes or behaviors (Oinas-Kukkonen 2013). While traditionally one person tries to persuade the audience, in case

[3] Note that in modern cohorts each student has a laptop. Thus, lab hours simply need a space where Teaching Assistants or Supplemental Instructors are available to support the students.

of persuasive technology, the intention to influence others can come from the designers of the technology, or those using it (Fogg 1998). In other words, the persuader can be the designer of technology, an entity who implements it and grants access to it, or the users trying to encourage themselves to perform intended behaviors. Regardless of these definitional perspectives, the characteristics of digitalized artifacts: programmability, addressability, senseability, communicability, memorizeability, traceability, and associability (Yoo 2010), and the functional affordances they engender for different users (Markus and Silver 2008) are central elements of the design of persuasive technology. For example, IT limits social cues and reduces control over time and place of processing of persuasive messages by the receiver (McKenna and Bargh 2000). But it also enables persuasive interactions that are difficult or impossible to achieve in interactions between humans, like scaling of individualized exchanges and persistence (Fogg 2003).

Persuasive technology is a nascent field of inquiry. It operates at the intersection of users' motivation and ability where technology is designed to reduce barriers to behavior performance, increase motivation to perform the behavior or stimulate behavior performance by way of appropriate triggers (Fogg 2009a). A trigger is any prompt, cue, call to action produced by the system "that tells people to perform a behavior now" (Fogg 2003). There are three types of triggers (Fogg 2009b):

- Spark: a trigger designed to increase motivation. For example, Flood Prevention is a game-initiated-learning software designed to increase students' motivation to learn about disaster prevention (Tsai et al. 2015).
- Facilitator: a trigger designed to reduce barriers to accomplishing the behavior. For example, an app promoting healthy lifestyles can use the smartphone camera and image processing to estimate food and calories consumption in order to improve adherence to a correct diet (Purpura et al. 2011).
- Signal: a trigger that prompts the behavior. For example, Apple Watch users are familiar with the reminders the device produces every hour to prod them to stand up and move around.

While the notion of triggering is intuitively appealing, the difficulty lies in triggering the behavior at the appropriate place and time to prompt action without frustrating or annoying the recipient (Intille 2004).

The third principle of intervention theory is internal commitment. There is very little work applying persuasive technology principles to college level education. However, given the tech savvy nature of the individuals our proposed design targets, we suggest that persuasive technology is a key enabler of the intervention and a promising avenue for fostering students' internal commitment to the learning objectives of the course. Modern college students are digital natives, comfortable users of personal IT. Thus, they are well suited for interventions that leverage persuasive technology designed to foster their ownership of the learning process and to motivate them to stay dedicated to their learning goals. Appropriately designed persuasive technology should help instructors efficiently provide students in large courses with the personalized attention and support typical of a small class. Given the high demands on the time of first-year college students and the confusion that often surrounds their adjustment to college (Chambliss and Takacs 2014), a particularly promising tool is the use of triggers.

MR6: The ST artifact supporting large introductory college courses proactively triggers appropriate behaviors

- DP6.1: Utilize signal triggers to remind students of deadlines and commitments (e.g., assignment deadlines).
- DP6.2: Utilize spark triggers to alert at-risk students and urge them to action.
- DP6.3: Utilize facilitator triggers to reduce obstacles to performing appropriate behaviors (e.g., prompting a "question of the day" through a conversational interface).

Triggers engender risks. Persuasive technology theory posits that urging action at times when students are unable to perform it risks causing frustration. Stimulating behavior when students are not motivated is likely to provoke annoyance (Fogg 2009a). Thus, attention should be devoted to identifying the most opportune time for triggering behavior by eliciting individual preferences and respecting individual differences.

MR7: The ST artifact supporting large introductory college courses encourages sustained use by students by managing triggering risks.

- DP7.1: Signal triggers are contextually aware (e.g., reminders are targeted, rather than unqualified “gentle reminders”).
- DP7.2: Students can customize the acceptable triggering window (e.g., time of day, day of week) or suspend triggers (e.g., mute for the day).
- DP7.3: Students can manage the type of triggers they receive (e.g., Requesting a “question of the day”).

While the proposed design leverages persuasive technology, the implementation recognizes the centrality of human interactions in learning environments. Thus, none of the design and implementation elements of the ST artifact should substitute human interaction or optimize for reduced interactions.

Table 3: Design Principles to Functionality Mapping for Existing Commercial Software

		Moodle (LMS)	**SAKAI (LMS)**	**Clickers**	**Automatic Graders**	**LearnSmart (course solutions)**	**SIMnet (course solutions)**	**Mika – Carnegie Learning (analytics)**	**Netex – smarted (analytics)**
MR1	DP1.1			X					
	DP1.2	X	X			X	X	X	X
	DP1.3	X	X			X	X	X	X
	DP1.4								
MR2	DP2.1								
	DP2.2								
	DP2.3								
MR3	DP3.1								
	DP3.2				X				
	DP3.3	X	X		X		X		
MR4	DP4.1	X†						X	X
	DP4.2	X†						X	X
MR5	DP5.1	X†						X	X
	DP5.2								
MR6	DP6.1	X*	X*			X*	X*	X*	X*
	DP6.2								
	DP6.3								
MR7	DP7.1								
	DP7.2								
	DP7.3								

* Only available as an alert if the student proactively logs into the system
† Via third party plugin.

Despite the importance of the problem area and the long tradition of research on college courses, our analysis of available applications and software solutions reveals significant coverage gaps with respect to our design principles. These gaps are particularly apparent in functionalities that require the use of triggers and for organization-dominant design principles (Table 3).

Discussion

The higher education "industry" has not been immune to digital transformation. However, there is a growing consensus in the literature that delivering high quality college education hinges on the instructor's ability to engineer a learning environment where students can learn effectively (Bain 2004). Thus, despite being a special case of digital transformation, in a specific context, our research is primarily a call to the importance of explicitly addressing unintended consequences of digital transformation – what we have termed the "dark side" of digital transformation. The historical analysis of the evolution of the current course over the past two decades shows the emergence of unintended consequences. The original course design was based on a rigorous analysis of its effectiveness as compared to the existing learning environment at the time (Piccoli et al. 2001). However, design efforts became less proactive over time and technology choices and activities became increasingly driven by resource constraints and the availability of "course solutions." This drifting of the design over time was apparent in the changing emphasis toward practical skills. Such innovation trajectories are common in digital transformation where the malleability and generativity of artifacts endow users with considerable freedom over the way they appropriate the innovation (Yoo 2010). While these "wakes of innovation" often yield positive outcomes (Boland et al. 2007), digital transformation may also have a dark side of unintended consequences. In our case, we identified three unintended consequences: role reversal, minimization of human interaction, and strategic learning.

Our observations are deeply contextualized in the college education environment, but they are in line with recent theorizing about digital innovation in general. Recent research has called attention to the need for further theorizing by positing how, as "some of our core organizing axioms may be challenged or fundamentally changed by the digital revolution," (Benner and Tushman 2015, p. 2) innovation processes and outcomes are no longer distinctly different phenomena (Nambisan et al. 2017). Rather, innovation is increasingly the outcome of dynamic problem-solution pairings (von Hippel and von Krogh 2015). This realization is particularly critical in the context of digital transformations, where the malleability and heterogeneity of digital technology lead to unprompted changes driven by uncoordinated and diverse actors (Yoo 2010), thus creating fertile grounds for positive, as well as unintended consequences. We argue that in this environment it is critical for intervention designers to gain clarity and maintain a disciplined focus on their objectives. In other words, while exploiting the generative qualities ST artifacts – such as a learning environment enabled by persuasive technology – the design must be bounded by deep seeded beliefs about the acceptable outcomes (e.g., the centrality of human interactions in learning environments). We use our proposed redesign, guided by the design science research paradigm, to illustrate this point. The explicit articulation of meta-requirements and design principles grounded in established kernel theories forces a continued re-evaluation and attention to the coherence of the ST artifact design and its rationale, in our case, the primacy of human interaction in the learning environment.

Conclusions

Digital transformation and digital innovation have become "imperatives" for modern organizations. Pervasive digitization and the digital mediation of everyday activities (Yoo 2010) have spurred calls for information systems researchers to contribute "theories that explicitly incorporate the variability, materiality, emergence, and richness of the socio-technical phenomenon called digital innovation" (Nambisan et al. 2017, p. 224). In this paper, we call attention to the importance of explicitly addressing unintended consequences of digital transformation in this theorizing. We do so by juxtaposing a historical case study of an actual digital transformation, with an alternative design stemming from the application of design science research principles. We show the value of an alternative approach, grounded in the design science research paradigm, that yields explicit choices substantiated in clear design principles directly stemming from clearly stated goals of the intervention.

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