Chapter 5
The CHI of Teaching Online: Blurring the Lines Between User Interfaces and Learner Interfaces

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Abstract The growing prevalence of online education has led to an increase in user interface design for educational contexts, and especially an increase in user interfaces that serve a central role in the learning process. While much of this is straightforward user interface design, there are places where the line between interface design and learning design blur in significant ways. In this analysis, we perform a case study on a graduate-level human-computer interaction class delivered as part of an accredited online program. To evaluate the class, we borrow design principles from the HCI literature and examine how the class's design implements usability principles like equity, flexibility, and consistency. Through this, we illustrate the unique intersection of interface design and learning design, with an emphasis on decisions that are not clearly in one design area or the other. Finally, we provide a brief evaluation of the class to endorse the class's value for such an analysis.

5.1 Introduction

The rising role of technology in education has led to a blurring of the lines between user interface design and learning design. The requirements of teachers, students, administrators, and parents dictates elements of the design of user interfaces used in educational contexts, but the design of those interfaces in turn fundamentally alters the learning process. At times, specific design decisions or elements of instruction cannot solely be attributed to learning design or user interface design.

This trend has existed for decades, from classic interfaces for correspondence learning to more modern learning management systems, but it has taken on a new significance with the advent of entirely online learning environments. While in some ways these learning environments are a natural evolution of these prior interfaces, the fundamental change that has occurred is the placement of the user interface as

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E. Kapros and M. Koutsombogera (eds.), *Designing for the User Experience in Learning Systems*, Human–Computer Interaction Series,
https://doi.org/10.1007/978-3-319-94794-5_5

the core of the class experience. Rather than complementing traditional classroom experiences with learning management systems or in-classroom technologies, these online learning environments *are* the classroom.

As a result, for perhaps the first time, the classroom itself is a user interface. This can be taken very literally, as with synchronous virtual classroom environments (Koppelman and Vranken 2008; Martin et al. 2012; McBrien et al. 2009), or it can be taken more figuratively, where user interfaces can serve the same functional roles as traditional classrooms while eschewing the typical requirements of synchronicity and telepresence (Hiltz and Wellman 1997; Joyner et al. 2016; Swan et al. 2000). These latter classrooms are particularly notable because the interface changes the interaction more fundamentally; whereas synchronous virtual classrooms may aim to recreate in-person interactions as completely as possible, asynchronous learning environments must use these computational interfaces to create the same effects through different mechanisms. Significant work has been devoted to investigating how these interfaces may replicate components of traditional learning environments, such as peer-to-peer learning (Boud et al. 2014), peer assessment (Kulkarni et al. 2015), social presence (Tu and McIsaac 2002), laboratory activities (O'Malley et al. 2015), and academic integrity (Li et al. 2015; Northcutt et al. 2016).

This trend toward interfaces *as* classrooms brings new emphasis to the intersection between learning design and user interface design. The two are highly compatible: principles like rapid feedback are comparably valued in user interface design (Nielsen 1995) and learning design (Chandler 2003; Kulkarni et al. 2015). However, it is also important to understand the nature of desirable difficulties (Bjork 2013; McDaniel and Butler 2011) within the material, as an interface designer may inadvertently undermine the learning experience in pursuit of higher user satisfaction (Fishwick 2004; Norman 2013). For this reason, we must carefully prescribe principles and guidelines for designing learning interfaces that emphasize when the roles of student and user are compatible.

Thus, due to both the advent of fully online learning environments and the underlying similarities between user interface design and learning design, there is tremendous opportunity to examine the user experience in learning systems from the perspectives of both interface design and learning design. However, the different objectives of the two design paradigms—one to support immediate interaction, the other to support long-term learning gains—mean that the application of one paradigm's heuristics and guidelines to the other must be performed carefully. Toward this end, some work has already been performed evaluating user interface design specifically within the realm of digital learning environments (Cho et al. 2009; Jones and Farquhar 1997; Najjar 1998), but relatively little work has been done on specifically the user interface design of fully online learning environments.

In this analysis we perform a case study on a graduate-level class offered as part of an online Master of Science in Computer Science program at a major public university. Both the program and the class are delivered asynchronously and online, with no requirement for synchronous activities or in-person attendance. While considerable attention could be paid to evaluating the specific user interfaces that deliver the program, this case study instead focuses on higher-level design decisions. Specifically, we are interested in transferring principles of human-computer interaction into the realm of learning design, especially insofar as their application is facilitated by the online nature of the program.

To do this, we first provide some necessary background on the nature and structure of the program and this class, and then move through four prominent principles from the human-computer interaction literature: flexibility, equity, consistency, and distributed cognition. For each topic, we examine how it transfers into this online learning environment as a principle of both interface design and learning design. We also look at a smaller number of additional principles with narrower applications in this course, and then evaluate the course based on student surveys.

5.2 Background

While this case study focuses specifically on a single class, that class exists in the context of a broader online Master of Science program at a major public university in the United States. Several of the principles we observe in this class are actually derived from the broader principles of the program, especially as it relates to equity. Thus, we begin by giving a brief background on the program, and then focus more specifically on the course under evaluation in this case study.

5.2.1 Program Background

The course under evaluation in this case study is part of an online Master of Science in Computer Science program launched by a major public university in the United States in 2014. The program merges recent MOOC-based initiatives with more classical principles and approaches to distance learning. The goal is to create an online program whose learning outcomes and student experience are equivalent or comparable to the in-person experience; as such, the program carries equal accreditation to the traditional on-campus degree.

In drawing inspiration from MOOC initiatives over the past several years, however, the program emphasizes low cost and high flexibility. On the cost side, the cost of attendance is $170 per credit hour plus $200 in fees per semester of attendance. Thirty credit hours are required to graduate, and thus, the total degree costs between $6100 and $7100, a small fraction of comparable programs or the university's own on-campus program. These costs are digestible because each class draws dramatically higher enrolment than their on-campus counterparts: as of Spring 2018, the program enrolls over 6,500 total students taking an average of 1.4 classes per semester, with individual courses enrolling as many as 600 students.

On the flexibility side, the program emphasizes that it requires no synchronous or collocated activities: students are never required to attend a virtual lecture at a specific time or visit campus, a testing center, or a remote lab for a course activity.

Proctored and timed exams are typically open for three to four days at a time, while lecture material is pre-produced and assignments are published well in advance of the due date.

The program thus captures an audience for whom a Master of Science in Computer Science is otherwise inaccessible, either due to high costs, geographic immobility, or scheduling constraints. Evaluations have shown that as a result, the program draws a dramatically different demographic of student from the university's on-campus program: online students tend to be older, are more likely to be employed, have more significant prior education and professional experience, and are more likely to be from the United States (Goel and Joyner 2016; Joyner 2017). The program is forecast to increase the annual output of MSCS graduates in the United States by 8% (Goodman et al. 2016).

5.2.2 Course Background

This case study focuses on one specific course in this broader program. Fitting this analysis's contribution, the course is on human-computer interaction, and covers HCI principles, the design life cycle, and modern applications such as virtual reality and wearable computing. At time of writing, the course has been offered four complete times, including three 17-week full semesters and one 12-week summer semester.

Each week, students watch a series of custom-produced lecture videos, complete a written assignment, and participate in peer review and forum discussions. Participation is mandated by the course's grading policy, but students have multiple pathways to earning participation credit to fit their personalities and routines. Students also complete two projects—one individual, one group—and take two timed, proctored, open-book, open-note multiple choice exams. Proctoring is supplied by a digital proctoring solution, allowing students to take the exam on their own computer.

Aside from the exams, all work is manually graded by human teaching assistants. One teaching assistant is hired for approximately every 40 enrollees in the course, and teaching assistants are solely responsible for grading assignments: course administration, announcements, Q&A, office hours, etc. are all handled by the course instructor.

The course generally enrolls 200–250 students per semester, supported by 5–6 teaching assistants. Its completion rate is 92%, ranking slightly higher than the program's overall average of approximately 85%. To date, 708 students have completed the course across four semesters, with 205 more on track to complete the course this semester.

To explore the crossover between interface design principles and learning design, we take four common design principles or theories from the HCI literature—flexibility, equity, consistency, and distributed cognition—and examine their applications to the design of this online course. In some ways, these principles are applied by analogy: flexibility, for example, traditionally refers to flexible interactions with a specific interface, but in our case, refers to flexible interactions with course material. In others, the application is more literal: equity, for example, refers in part to accommodating individuals with disabilities, which is more directly supported by the course and program structure.

5.3 Flexibility

For flexibility, we apply the Principle of Flexibility from Story, Mueller and Mace's Principles of Universal Design, which they define as, "The design accommodates a wide range of individual preferences and abilities" (Story et al. 1998). We also inject the heuristic of Flexibility and Efficiency of Use from Jakob Nielsen's ten heuristics, where he writes, "Allow users to tailor frequent actions" (Nielsen 1995). The flexibility of the course generally flows from the inherent properties of the online program, although the course design takes care to preserve and accentuate this flexibility. Most importantly, these applications of the principle of flexibility support the subsequent applications of the principle of equity.

5.3.1 Geographic Flexibility

Geographic flexibility refers to the online program's ability to accept students regardless of their geographic location. At a trivial level, this relates to the program's ability to accept students who do not live within range of campus. As it pertains to flexibility as a usability guideline, however, this flexibility relates more to accommodating individual preferences for where they complete their work. This relates in part to individual circumstantial constraints, such as the need for working professionals to be able to take course material with them during work trips. It has more significant implications, however, especially as flexibility ties into equity: for example, individuals with disabilities that deter them from leaving the house may participate in a program that offers true geographic flexibility. In a computer science program, several of the abilities required for in-person attendance (e.g. walking, driving to campus, relocating to campus) are largely unrelated to the material itself, and thus this geographic flexibility resolves individual characteristics that pose threats to a student's participation in the field that are unrelated to the content.

It is worth noting that geographic flexibility is inherent in distance learning as a whole; this class's instantiation of geographic flexibility is not unique except insofar as an identically-accredited distance learning program at a major public institution is still somewhat novel.

Table 5.1 Enrollment and number of instructor and student forum contributions by semester

Statistic	Fall 2016	Spring 2017	Summer 2017	Fall 2017
Enrollment	83	231	183	211
Student contributions	3,477	9,147	7,970	9,381
Instructor contributions	785	1,768	1,143	1,265

5.3.2 Temporal Flexibility

Temporal flexibility refers to flexibility of the student's time, allowing them to work on the class not only wherever they want, but whenever they want. Temporal flexibility offers a greater difference between this program and traditional distance learning as the presence of live interaction has typically differentiated distance learning from correspondence learning. Given the program's goals of equality with the on-campus program, however, simplifying delivery to correspondence education would be insufficient; requiring live interaction, however, would challenge temporal flexibility.

The class achieves balances these competing needs by maximizing the usage of asynchronous communication tools in course delivery. Most course forums garner over ten thousand posts per semester, with approximately 80% coming from students and 20% coming from the instructor. Table 5.1 shows the class's enrollment and contribution statistics by semester. In addition to forum participation, the class also leverages asynchronous tools for peer review and instructor feedback, as well as an asynchronous video-based method for disseminating pre-recorded custom-produced lecture videos.

This temporal flexibility refers strictly to those activities that are typically synchronous in traditional course delivery. Other activities, such as completing homework, are usually somewhat asynchronous. As a result, the design of this course accommodates individual students with a wide range of preferences or constraints on when they work on course material. We will discuss the impacts of this more in the section below on equity.

5.3.3 Preference Flexibility

The geographic and temporal flexibility described above give way to an abundance of flexible accommodations for individual students' preferences and abilities. For example, as a product of being able to watch and re-watch lectures at any pace and in any setting, students may choose to watch lectures while actively working on the assignment they target; to attempt an assignment prior to watching the lecture videos in order to pre-load questions to consider while watching; or to only watch the videos as needed knowing that lecture material cannot be permanently missed the way a single in-person class may be missed.

For this course, flexibility is extended through the course's participation policy as well. It is common for online courses to attempt to capture in-person participation by requiring forum participation, but most research instead focuses on incentivizing or encouraging it more authentically [e.g. Kizilcec et al. (2014)]. There are multiple reasons to focus on more organic discussion stimulation, not least among them that requiring such participation does not address recognized gender issues in forum communication (Freeman and Bamford 2004). To accommodate a greater range of student preferences, this course instead offers multiple routes to earning participation credit: students may contribute to the forums, complete peer reviews of their classmates' work, give instructors feedback on the course, or participate in their classmates' need finding or evaluation studies as part of their coursework. These different activities fit with different student preferences and behaviors; for instance, it is easier to set aside a block of time for peer reviews, whereas it is easier to participate in a course forum in several short moments of time.

5.4 Equity

In defining equity as a design principle, we borrow in particular the Principle of Equitable Use from Story, Mueller, and Mace, which they define as "The design is useful and marketable to people with diverse abilities" (Story et al. 1998). In particularly, we note the sub-guidelines, "Provide the same means of use for all users: identical whenever possible, equivalent when not" and "Avoid segregating or stigmatizing any users" (Story et al. 1998).

Our application of equity begins with the natural consequences of the flexibility described above; flexibility focuses on what students within the program can do, but equity focuses on what students can participate due to that flexibility. We then examine equity as well as facilitated by the program's admissions structure and pseudo-anonymity in course delivery.

5.4.1 Equity Through Flexibility

In many ways, the greatest advantage of the geographic and temporal flexibility referenced above is not in the experience of students in the program, but rather in what students may enter the program in the first place. A traditional graduate program draws from a very narrow population: individuals (a) who either live near the university or have the financial or lifestyle flexibility to relocate, and (b) have the scheduling flexibility to attend classes during the day or pre-selected evenings. Financial flexibility plays into this as well: a traditional graduate program is only available to those who have or can secure (through loans or employer reimbursement) the funds to pay high tuition rates.

Because this program is available to students regardless of location or specific scheduling availability, it is equally available to students who otherwise would lack the ability to participate in such a program. The requirements are distilled down to only those that are inherently required for the content: a significant time commitment (albeit flexible to the student's own schedule) and sufficient prior background. The cost supports this equity as well: while still expensive, the program does not demand access to an exorbitant amount of funds. As noted previously, these factors directly correspond to the unique demographics the program draws (Goel and Joyner 2016; Joyner 2017).

It is worth noting that this audience is not one for which we might stress equity: students entering the program must have a bachelor's in computer science or a similar field with a strong GPA (or equivalent work experience); these criteria generally mean the students are advantaged in the first place. Thus, one takeaway of this program's application of the principle of equity comes instead in how similar models may be extended to otherwise-disadvantaged populations. However, another application comes in expanding the view of the program's audience from geographically dispersed mid-career working professionals and considering also individuals with chronic illnesses, caretakers for others with illnesses, expecting parents, and others for whom obstacles to participation exist.

5.4.2 Equity Through Admissions

One component discussed above is the program's size: at 6,500 students, it is believed to be the largest program of its kind in the world (Goodman et al. 2016; Joyner 2018). While this is often discussed as part of counterbalancing the low tuition rate, it has a profound effect on equity as well. While the program's on-campus analogue sets a minimum bar for acceptance, it draws far more qualified applicants than it has capacity to handle. As a result, the top few percent are admitted, leaving out many students who meet the minimum requirements but are not competitive with the most-decorated applicants.

As the online program lacks a set capacity, however, any student who meets the minimum requirements is admitted. This expands access to students who otherwise would be uncompetitive, typically due to a more meager prior background. These students meet the minimum requirements and stand a strong chance of succeeding, but they would not be in the top percentile of applicants typically accepted to a limited-capacity program. Thus, the limitless capacity supports the principle of equity by accepting students with the potential to succeed who may not otherwise have the opportunity.

5.4.3 *Equity Through Anonymity*

A classic internet aphorism states, "On the internet, no one knows you're a dog." In some ways, the principle applies to this program: although students are identified by name and work is tied to their real identity (unlike MOOCs, where a username may supplant a true name), students have considerable control over what portions of their identity they reveal to classmates and instructors. To classmates, students have the option to reveal essentially no personal information: they may select the name that is shown in discussion posts and peer review, which typically are the only communications inherently surfaced to classmates. Even to instructors, students reveal little about their personal selves.

While a systematic study of this dynamic is still in the works, we have anecdotally observed several applications. At a broad level, it is known that there are issues with perceived identity mismatches between gender or race and computer science (Whitley 1997), and that merely being reminded of such stereotypes can lessen performance and engagement (Good et al. 2003). Signifiers of these stereotypes are inherently present in traditional classrooms, but online lack any inherent need to be disclosed. It is worth considering whether hiding these signifiers is a missed opportunity in the long run, but it nonetheless presents a path around stereotype threats worth considering.

Other applications of this anonymity are even more delicate, demanding caution in conducting more rigorous studies, but they nonetheless reveal enormous potential for equity through the relative anonymity of the online delivery mechanism. Students have on multiple occasions confided in trusted instructors or teaching assistants the presence of mitigating issues that alter their in-person interactions, including physical disabilities or deformities, obesity, speech impediments, transgenderism, and behavioural disorders. The online environment removes these as a first impression among classmates and with instructors, creating an equity of experience among those populations least likely to find it in person.

5.5 Consistency

As a design principle, consistency appears across multiple sets of guidelines and heuristics. We apply the definitions from three different such sets. First, Norman states (Norman 2013),

> Consistency in design is virtuous. It means that lessons learned with one system transfer readily to others … If a new way of doing things is only slightly better than the old, it is better to be consistent.

Nielsen prescribes a similar heuristic, stating, "Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions" (Nielsen 1995). Constantine and Lockwood echo these sentiments as well with their Reuse Principle, stating (Constantine and Lockwood 1999),

> The design should reuse internal and external components and behaviors, maintaining consistency with purpose rather than merely arbitrary consistency, thus reducing the need for users to rethink and remember.

With regard to this case study, we consider especially consistency within the class: just as consistency is used to set expectations among users of the outcomes of different interactions, so also consistency is used to set expectations among students of certain responsibilities or deliverables. Efforts are underway as well to extend consistency across courses, especially as they relate to administrative elements of course delivery.

5.5.1 Assignment Cadence

Early on, we observed that in delivering an asynchronous class, a forcing function for students' regular engagement was lost. On campus, that engagement came from lectures: even if assessments were only due every month, students were still incentivized to remain engaged by the fleeting lectures which could not be recovered once lost. In this online design, all lecture material is persistently available: what, then, is there to motivate students to remain engaged long before assessments are due?

Our approach to this is to manually recreate that cadence of a weekly engagement through weekly deliverables. The class requires student submissions every week of the semester, each of which directly corresponds to the recommended lecture material for the week. Flexibility (and its effect on equity) are preserved in that lectures and assignment descriptions are all provided at the start of the semester, so students who need to work around other constraints may do so by working ahead; regular deadlines, however, force the majority of students to remain engaged with the course on a weekly basis. Just as through the principle of consistency in interface design a user can interact with a new interface and understand the outcomes of their actions, so also a student can enter a new week of the course and understand the expectations without re-reading the calendar.

5.5.2 Announcement Cadence

Just as in-person lectures serve as a forcing function for continued student engagement, we also observed that they serve as a hub for course communication. A natural expectation arises (even if only in the minds of instructors) that weekly lectures will set expectations for the week or recap the week. The loss of this dynamic risks a class becoming a single amorphous semester rather than a regimented curriculum, especially with students' tendencies to do work at non-traditional times [e.g. weekends (Joyner 2017)].

To combat this, the course leverages consistent weekly announcements, sent to students every Monday morning and Friday evening. Monday announcements remind students what they are expected to watch, read, and do for the week, while Friday announcements typically recap significant occurrences or reemphasize key points from the week's material. These announcements aim to further emphasize that classroom cadence, replicating the effect of a teacher walking in on Monday morning and beginning lecture. As an application of consistency, this replicates common interaction designs such as weekly reports or digests of activity, acting as consistent reminders that the course is ongoing.

The announcement cadence plays a more significant role as well with regard to the course's emphasis on distributed cognition, explained further in the next section. Either way, these weekly announcements are the single most well-praised element of the course's delivery, and have been incorporated into recommendations issued to all classes in the program.

5.5.3 *Administrative Decisions*

As a more literal application of the principle of consistency, the course makes several administrative decisions to create consistent expectations among students regarding more trivial elements of the course experience. The course's smallest unit of time is one week: there are no in-week deadlines (excepting a small incentive for early peer review discussed later). Sunday night at 11:59 PM UTC-12 (anywhere on earth) time marks the end of each week; all of the week's work is due at this time, and one minute later marks the start of the next week. Anywhere on Earth time is chosen to simplify planning for students: if it is before midnight their local time, the assignment is not due. We encourage students to submit by their own midnight for simplicity, although our experience is that students maximize the time available, and submissions role in late in the evening on Sunday nights.

Few course components are time-gated (exams, periodic course surveys), but those that are open at 12:00 AM UTC-12 on Mondays, closing at the typical deadline as well. Thus, students do not devote cognitive resources each day to considering what is required; only on Sundays are students required to ensure they have accomplished the week's deliverables. As a principle of consistency, this process similarly aims to diminish students' reliance on repeated manual checks and increase the time allotted to focus on the course material and assessments.

Interestingly, we have attempted to leverage the principle of consistency in other ways, such as scheduling the aforementioned announcements to go out at the exact start of the week. Feedback we have received from students, however, indicates this is actually somewhat counterproductive as it diminishes the personal feel of these announcements: students feel more connected to the class knowing the instructor was physically present to send the announcement, even if it is delayed. This suggests this principle is best applied to items around which students plan, such as deadlines and release dates, rather than every element of the course delivery. It may also be the case that students are patient with late announcements because expectations of consistency and fairness are set in these other ways.

5.6 Distributed Cognition

Where the previous four design principles were stated with some clarity in a well-known prescriptive set of guidelines, distributed cognition is a more general theory through which we may examine human-computer interfaces (Hollan et al. 2000). Key to this idea is the notion that human cognitive tasks like reasoning, remembering, and acting could be offloaded onto a computer interface to lighten the cognitive load on the user. As applied to education, this suggests using an interface to lessen the attention paid by students to course administration to support greater attention to course content.

5.6.1 Offloading Through Announcements

As referenced above, in addition to creating consistent expectations, a major function of regular announcements is to offload the attention students may otherwise spend thinking about course procedures, assignment deadlines, and so on onto the interface, allowing them instead to focus on the course material. This role of these announcements comes from an early observation from students: whereas traditional in-person courses operate on a "push" structure, online courses emphasize a "pull" structure. These terms, derived from principles of HCI as well, mean that students in a traditional class can usually rely on the instructor to push information to them, such as by standing in front of a lecture hall and giving announcements. Online classes usually operate by making all information available to the students, but that relies on students pulling the right information at the right time.

Weekly announcements approximate that in-person dynamic by pushing immediately pertinent information to students. Students thus do not need to trust that they have pulled all critical information at the right time; absent this trust, students devote significant cognitive resources to attending to the class's administration, which diminishes the resources that may be devoted to learning the actual course material. As noted above, this is a small feature, but it is one of the most well-praised features in the program; student reviews on a public student-run review site praise this repeatedly, and other pieces of negative feedback could be similarly addressed by offloading these roles onto the interface.

5.6.2 *Offloading Through Documentation*

A second application of distributed cognition to the course design leverages the student community more heavily. As referenced previously, the online environment makes heavy use of the course forum, but it takes on a unique role in the online course: it *is* the classroom, but it is a classroom where any student can contribute at any time (Joyner et al. 2016). Student answers to classmates' questions are not often emphasized in traditional lectures where students inherently pose questions to the professor, but the online board affords student-to-student discussion more fully.

This provides an answer to another implicit question in course design: what information should be incorporated into the course's fundamental documentation, and what should be pushed to students through announcements and discussions? This course errs heavily on the side of the documentation specifically because it leverages this student community: the community as a whole can come to a common understanding of the course's administration and policies because the entire documentation is available to everyone. Any single student likely will not read all the documentation, but enough students will read each part that if a student has a question that is covered in the documentation, some classmate will have the answer. Thus, knowledge of the course is distributed among the student body rather than solely relying on the communication of the instructor.

5.6.3 *Offloading Through Assessment Design*

Finally, the course deliberately designs assessments to encourage students to leverage distributed cognition. While this is natural in essays and projects where course access is persistent during work, the course tests are also designed to be open to any non-collaborative information seeking. These open-book, open-note, open-video, open-forum tests are created with the knowledge that students will have access to course resources, and thus should focus less on the knowledge they are able to draw to mind immediately and more on their ability to solve questions quickly with the available resources.

Students are informed of this paradigm in advance of the exams, and encouraged to organize their test-taking environment accordingly. Ready access to course material, their notes, the readings, and even the course's discussions are encouraged. These tests emphasize that it is the system comprised of the student, their resources, and their environment that is being assessed on the test rather than just their cognition. Distributed cognition is thus simultaneously a lesson in the course, a principle for students to apply to the course, and a theory for us to apply in evaluating the course.

5.7 Additional Principles

Additional principles are at play in the course as well, although we generally note that many of these principles apply equally well to traditional courses using modern-day learning management systems. Nonetheless, they are worth including as they further broaden the view of how interface design principles may be applied to learning design.

5.7.1 Structure

With regards to structure as a principle of design, we leverage the principle defined by Constantine and Lockwood (1999). In many ways, our applications of structure are not inherently restricted to online environments; however, we observe that specific details of the online environment more clearly afford visible structure. We observe, for example, that organizing lecture material into pre-produced videos allows the presentation of it in a way that brings out the underlying structure of the content rather than forcing it into a prescribed lecture schedule. This, then, allows students to construct their consumption of course material around the actual structure of the content.

This similarly connects to the structure of a course calendar offered to students: without requirements that a pre-set amount of time be spent in certain weeks in lecture, the structure of the course can be more deliberately designed not only for the content, but also for the assessments. Other classes in the program, for example, implicitly require students to "attend" ten hours of lecture in the early weeks of the class, then shift to a strict project-based mode in the later weeks. Such a structure would not be possible in a traditional system of prescribed lecture times.

5.7.2 Perceptibility

On perceptibility, Nielsen writes, "The system should always keep users informed about what is going on, through appropriate feedback within reasonable time" (Nielsen 1995). An education application of this heuristic has emerged as a somewhat natural consequence of the advent of learning management students: students retain persistent access to the gradebook for immediate perceptibility of their current status in the class. Although Nielsen focuses on this as a pushing relationship where relevant information is pushed to the user, this availability instead facilitates a pulling behavior allowing the student to pull information when pertinent to them.

We have seen this principle emphasized more heavily in other courses, especially those reliant more on automated evaluations. An online CS1 course offered by the same university provides automated evaluators for every course problem, all of which feed an immediately-available gradebook (Joyner 2018). This even more dramatically the perceptibility of what is going on with a student's grade, and while this is compatible with traditional classes, it takes on a new emphasis when the entire experience is in an online environment based on immediately-perceptible feedback.

5.7.3 Tolerance

Regarding tolerance, the Principles of Universal Design state that a good design "minimizes hazards and the adverse consequences of accidental or unintended actions" (Story et al. 1998). In education, the level of tolerance for content-specific answers is often dictated by the field rather than by the learning design. However, interface design and learning design can merge to create a tolerance for mistakes more related to administration and policies instead of content errors. In this course's learning management systems, it is possible to separate an assignment deadline (shown to the students) and an assignment close date (hidden from the students); this course uses these features to set a two-hour grace window after the official deadline where submissions are still accepted. This creates a tolerance for minor errors, such as incorrectly converting the UTC-12 time zone to one's local time zone or underestimating the time it will take to move through the submission screens to upload an assignment.

This course also builds tolerance for late work into its process for rapidly evaluating assignments. After an assignment's close date, a gradebook is exported with individual students assigned to individual grades. In the event that a student submits work even later than the grace period allowed by the learning management system, the course staff may quickly attach the submission to the row; if the grader has not yet completed their tasks, then accepting the late submission costs the grading team no time compared to if it had been submitted on time. While others address this with a strict grading policy, the size of the class means that a non-trivial number of assignments will have earnest reasons for late submission, and so the course builds tolerance into the grading workflow design.

5.7.4 Feedback

Regarding the common need for feedback, Norman writes (Norman 2013),

> Feedback must be immediate. … Feedback must also be informative. … Poor feedback can be worse than no feedback at all, because it is distracting, uninformative, and in many cases irritating and anxiety-*provoking*

Among all usability principles, the principle of feedback is likely the most easily transferrable between interface and learning design. Feedback holds the same meaning in both domains, providing actionable information on the outcome and correctness of an action.

As it relates to online course design, we see in this course two interesting applications where the course facilitates more rapid feedback. First, the scale of the course dictates heavy organization; the grading workflow described above follows almost an assembly line approach, where assignments are automatically distributed to graders, rubrics are formalized, and results are processed in batch. Research on the program shows that a significant amount of attention in the learning design process goes into exactly these grading workflows (Joyner 2018), and the result is a more rapid return rate than seen on campus due to the benefits of scale.

A second component comes from the course's method for implementing peer review. Students complete peer reviews as part of their participation grade, but as rapid feedback is more desirable, students are explicitly incentivized to complete peer reviews early. This is the only place in the course where a mid-week semi-deadline exists: students receive 50% more credit (1.5 points) for a peer review submitted within three days of its assignment's deadline, and 50% less credit (0.5 points) for a review submitted more than a week after the deadline. With each assignment reviewed by 3–4 classmates, this raises the likelihood that feedback will arrive rapidly; in the most recent semester, 58% of all peer reviews were submitted within 3 days, and 69% within one week.

5.8 Course Evaluation

Course evaluation has been the topic of considerable discussion in the learning sciences literature. Attempts have been made to create explicit evaluators of course or teaching quality (Biggs and Collis 2014; Ramsden 1991), but these often require standardized tests or high-effort qualitative analyses. In place of these, student reviews are often used as a low-cost approximation of course quality. While some early research found these types of surveys are decently correlated of learning outcomes (Cohen 1981), more recent research casts doubt on this correlation (Greenwald 1997; Uttl et al. 2017), suggesting student reviews are too biased especially by gender differences to be useful for comparisons (Andersen and Miller 1997; Centra and Gaubatz 2000).

In this analysis, we nonetheless use student reviews to add to the overall picture of the class in this case study. We acknowledge the weaknesses of student reviews as comparative tools, but note that (a) we are not using these student reviews to compare against another class, but rather merely to attest that the class is generally well-received by students, and (b) while most research on the validity of student reviews has been performed at the K-12 or undergraduate level, these reviews are submitted by graduate students who are also mid-career professionals, and thus we hypothesize are more valid assessors of course quality. Anecdotally, several professors in the program agree to the observation that online students appear to have far higher standards than their traditional counterparts.

These student surveys come from two sources: first, the institute issues a Course Instructor Opinion Survey open to every student in every class. Student identifies are strictly hidden in these surveys, and the results are known to inform institute-level evaluations of teaching. Second, the course itself issues an end-of-course survey asking questions more specific to its own unique details.

5.8.1 Institutional Surveys

At time of writing, the course from this case study has been offered four times: Fall 2016, Spring 2016, Summer 2016, and Fall 2017. At the end of each of these semesters, students were offered the opportunity to complete the institute's Course Instructor Opinion Survey for the course. The questions on this survey are dictated by the institute, and although no explicit incentive exists for students to participate, students are nonetheless highly encouraged to do so by the school and instructor.

All questions on this survey offer 5-point Likert-scale responses. Table 5.2 provides the interpolated medians to each of these prompts.

Based on these results, we make two notable observations. First, the ratings of course effectiveness and quantity learned have not changed semester to semester. This is notable because the course has undergone significant revisions semester to semester, suggesting that either these revisions do not affect the student experience (or the effect is too small for detection), or that students are unable to evaluate the effect of these changes absent a target for comparison. In particular, Fall 2017 added a significant reading component to the course requiring an additional 1–2 h per week of reading. With this change, 61.7% of the Fall 2017 class estimated they put 9 or more hours per week into the course, which is statistically significantly different from the percent reporting 9 or more hours in Spring 2017 (43.6%, $X^2 = 9.193$, $p = 0.0024$) or Fall 2016 (51.5%, $X^2 = 5.322$, $p = 0.0211$).[1] Despite this, student assessments of the amount of material learned did not change.

Secondly, these reviews suggest that the design decisions described herein are at least somewhat effective in supporting the student experience as students specifically comment positively on criteria that typically are considered lacking in online courses. Most notably, whereas online instructors are often considered detached or uninvolved (De Gagne and Walters 2009), students in this class specifically reflected positively on the instructor's enthusiasm (4.96/5.00), respect (4.96/5.00), availability (4.90/5.00), and ability to simulate interest (4.89/5.00). We hypothesize this is due in part to the singular ownership over course announcements, documentation, and scheduling attributed to the instructor, in line with existing research on the effectiveness of immediacy behaviors (Arbaugh 2001).

[1] Summer 2017 is excluded from this comparison as the semester is shorter and more work is deliberately expected per week.

Table 5.2 Interpolated medians of student responses to eight prompts on the institute-run end-of-course opinion surveys

Prompt	Fall 2016	Spring 2017	Summer 2017	Fall 2017
Response rate (%)	83	69	70	61
How much would you say you learned in this course?[a]	4.53	4.45	4.41	4.45
Considering everything, this was an effective course[b]	4.82	4.74	4.85	4.80
The instructor clearly communicated what it would take to succeed in this course[a]	4.89	4.89	4.93	4.90
Instructors respect and concern for students[c]	4.95	4.96	4.96	4.94
Instructors level of enthusiasm about teaching the course[d]	4.95	4.97	4.97	4.95
Instructors ability to simulate my interest in the subject matter[e]	4.90	4.86	4.89	4.89
Instructors availability for consultation[f]	4.88	4.89	4.93	4.87
Considering everything, the instructor was an effective teacher[a]	4.92	4.95	4.94	4.93

[a]From 5—Exceptional amount to 1—Almost nothing
[b]From 5—Strongly agree to 1—Strongly disagree
[c]From 5—Exceptional to 1—Very poor
[d]From 5—Extremely enthusiastic to 1—Detached
[e]From 5—Made me eager to 1—Ruined interest
[f]From 5—Highly accessible to 1—Hard to find

5.8.2 Course Surveys

While the institute-wide course surveys give some useful information, they are a bit constrained by the need to apply universally to all courses. To supplement these, the course offers its own end-of-semester survey asking questions more specifically targeted to the design and structure of the course itself. Table 5.3 provides these results.

As with the institute-level survey, the course-level survey provides some interesting insights. First, the numbers across most categories do not change semester to semester. This is notable not only because of changes made to the course as time goes on, but also because of semester-specific factors. Fall 2016, for example, was the first semester of the course, and students popularly consider the first semester a "trial run"; anecdotally, many students specifically avoid first-semester classes knowing the second run will be smoother, while other students deliberately take new classes because

Table 5.3 Interpolated medians of student responses to eleven prompts on the course-run end-of-semester opinion survey

Prompt	Fall 2016	Spring 2017	Summer 2017	Fall 2017
Response rate (%)	63	65	83	52
"The lectures were informative and easy to understand"[a]	6.71	6.60	6.56	6.66
"The exercises during the lectures kept me engaged"[a]	5.95	5.74	5.80	5.85
"The video lessons were valuable in helping me learn"[a]	6.78	6.56	6.59	6.67
"[The forum] improved my experience in this class"[a]	5.90	5.42	5.56	5.45
"The [peer review] system improved my experience in this class"[a]	5.29	5.51	5.46	4.92
Jump around in the lessons instead of watching in order[b]	1.82	1.84	1.91	2.13
Fall behind the recommended schedule in the syllabus[b]	2.17	2.17	2.12	2.26
Watch ahead of the recommended schedule[b]	2.55	2.05	2.11	2.15
Re-watch an entire lesson[b]	3.02	2.73	2.71	2.93
Re-watch only a portion of a lesson after having previously finished a lesson[b]	3.72	3.74	3.49	3.41
Watch videos through an app[b]	1.41	1.36	1.72	1.40
Download course videos for offline viewing[b]	1.38	1.31	1.37	1.34

[a] Agree or disagree, from 7—Strongly agree to 1—Strongly disagree
[b] How often, from 5—Always to 1—Never

they enjoy being early adopters. This may be visible in the data: students reported slightly more re-watching and watch-ahead behaviors during the first semester. It is unclear why peer review ratings are lower during Fall 2017.

Second and more significant to this analysis, however, is that we see a significant incidence of behaviors corresponding to the claims regarding equity from earlier in this analysis. Nearly all students report some re-watching behaviors with an interpolated median corresponding to 3 ("Occasionally") for rewatching lectures in their entirety and closer to 4 ("Frequently") for rewatching only specific parts. While data does not exist regarding why students engage in these behaviors, they are closely aligned with potential supports for sensory or attentional deficits. Similarly, while behaviors related to watching ahead, falling behind, or taking lectures “on the go” are rarer, a non-trivial portion of the class still reports leveraging these capabilities. These correspond to the applications of flexibility discussed previously, allowing students to integrate their course performance flexibly into their routine and schedule. Anecdotally, students report these behaviors most commonly in working around vacation or work schedules or integrating course participation into train commutes or travel plans.

5.9 Conclusion

In this case study, we have taken common principles from well-renowned literature on human-computer interact (Constantine and Lockwood 1999; Nielsen 1995; Norman 2013; Story et al. 1998) and applied it to the design of an entirely-online for-credit graduate-level course in human-computer interaction. We find that whether by analogy or by direct application, many of these principles are strongly related to both the goals and design of online education. Just as interface design aims to accommodate flexibility with regard to user preferences, so also a major objective of online education is to accommodate audiences for whom traditional education is too inflexible to fit into their lifestyle. Just as interface design strives to accommodate all audiences regardless of experience and personal factors, so also online education aims to give access to anyone who may succeed at the course material. Just interface design aims to shrink feedback cycles and emphasize attention to the underlying task, so also learning design in online education aims to offload non-content tasks onto the interface or leverage consistent expectations to minimize time spent thinking about course administration. Most notably, there are places where the lines between learning design and interface design blur: instructors take certain actions in the interface to implement the learning design, such as setting consistent deadlines to minimizes cognitive load or pushing announcements to students to offload progress-tracking onto the interface.

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