Learner and User Experience Research

An Introduction for the Field of Learning Design & Technology

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Acknowledgements

The editors would like to thank the authors, the editorial assistants, Rui (Tammy) Huang, Jackie Gishbaugher, and Jessica Gatewood, Jon Davison for his additional help with the editorial process, Royce Kimmons for his creation of the edtechbooks.org platform and support during the publication process, and Carla Schmidt for her patience and support.

Introduction to the Edited Volume

Learner and User Experience Research: An Introduction for the Field of Learning Design & Technology

Matthew Schmidt, Andrew A. Tawfik, Isa Jahnke, Yvonne Earnshaw, & Rui Tammy Huang

Instructional Design   Learning Technologies   User Experience   Learner Experience   User-centered Design

Human-computer Interaction   Learning Design

Researchers have been engaged in productive scholarly endeavors at the intersection of Learning Design, User Experience (UX), Human-Computer Interaction (HCI), and associated disciplines for some time. Our work as editors has sought to capture and disseminate the collective voices of authors working in this area within a single volume. This book focuses on explicating the ontological and epistemological underpinnings of user-centered design (UCD) and UX as applied in the field of Learning/Instructional Design & Technologies (LIDT) with the goal of foregrounding the importance of learner experience (LX) as an emerging design paradigm for the field of LIDT. This chapter introduces the 15 chapters of our open access edited volume. The book is clustered in three parts of (a) Methods and Paradigms (5 chapters), (b) Models and Design Frameworks (6 chapters), and (c) LX Design-in-Use (4 chapters). This volume serves as a contribution to an emerging, transdisciplinary, and complex phenomenon that requires multiple literacies. LX is not only concerned with the effectiveness of designed learning interventions, but also with the interconnected and interdependent relationship between the learner- (or the teacher-/instructor-) as-user, the designed technology, novel pedagogical techniques or instructional strategies, and the learning context. The diversity and breadth of perspectives presented herein serve as a topographical sketch of the emerging focus area of LX and represent an opportunity to build upon this work in the future.

1. Introduction

When the editorial team first conceived of this book, our vision was to create an introductory resource focusing specifically on the theory and practice of learner experience (LX) and user experience (UX) in the field of learning/instructional design and technology (LIDT). We recognized that interest in UX and LX is growing in the field of LIDT, but also that researchers and practitioners seeking to learn and apply related methods must seek guidance from outside of our field. We therefore recognized the need for an interdisciplinary resource on UX and LX in our field. With this edited volume, we hope to address this need and spur further scholarship in this area. In an effort to establish broad impact, we agreed that this resource should be published as open access and geared towards a range of audiences interested in LX design.

Ultimately, this work is predicated on the premise that the complexity of designing for learning with technology cannot be adequately informed on the basis of theories and models derived from educational psychology and learning sciences alone. Learners' individual, perceived experiences of interaction with learning technologies also must be considered as critically important to the learning process. Therefore, the two overarching goals that guided our efforts were:

- To explicate the ontological and epistemological underpinnings of user-centered design (UCD) and UX as applied in LIDT and
- To foreground the importance of LX as an emerging design paradigm for the field of LIDT.

To this end, we solicited multiple, diverse perspectives that considered theoretical and practical issues of UX and LX across disciplines, interfaces, methods, and platforms. Our initial call for chapter proposals attracted a vibrant assortment of manuscripts relating to UX and LX in LIDT. In the following sections, we provide our rationale for this edited volume, followed by a discussion of why we chose to publish it as open access. We then detail the main sections of the edited volume, and synthesize each of the chapters associated with each section. Finally, we conclude the chapter by presenting three broad conjectures that seek to characterize LX broadly, on the basis of our experiences developing this volume over the past year.

1.1. Why This Book?

Considerations of UX are core to many of the sister disciplines of LIDT (e.g., human-computer interaction, information technology), but historically, little attention has been given to LX or to the process of LX design in LIDT. With sister disciplines leaning towards more human-centered approaches to design, could this signal a shift in the field of LIDT? There is no question that user-centered design (UCD) methods increasingly are being applied in learning design contexts (Baek et al., 2008; Barab et al., 2005; Ebner & Holzinger, 2007; Fernandez-Lopez et al., 2013). However, in addition to learning design providing learners effective digital learning tools to efficiently propel them towards learning outcomes, learning designers should also be concerned with construction of digital learning tools that are pleasing and easy to use. Our collective experiences directing LIDT design studios and working in industry have underscored the importance of both (a) effective tools and ease of use and (b) meaningful pedagogies and theory. This is further supported by our experiences developing this edited volume, which has convinced us that researchers and practitioners are not only using a variety of methods and processes from human-computer interaction (HCI), UX, and UCD in LIDT, but are doing so quite ably and with very promising outcomes. The body of knowledge included in this edited volume serves as a testament that these human-centered methods and processes external to our field have proved to be useful for both scholarship and practical application in LIDT. On the surface, it is tempting to adopt the view that LXD could be a new and emerging focus area in our field, and admittedly, this could indeed be the case. However, closer inspection of the emerging LX phenomenon unveils a number of issues that bear further consideration, a selection of which we outline below.

Firstly, there is little agreement in terminology within our discipline. While terms like LX, LXD, LCD, and learning design have been readily adopted, it is unclear how they are defined. Indeed, many terms are used informally, interchangeably, and without precision. For example, learning experience and learner experience are both referred to as LX. What do these different terms mean? Are they fungible or distinct? What are their parameters and how are they operationalized? How do the concepts of learner/learning experience and learner experience design differ or overlap? Similar questions can be found in the tradition of HCI, where debate regarding how UX design is defined, situated, and performed is ongoing. In fact, it is in recognition of these debates that we have opted to use the more semantically established term "UCD" throughout the current chapter. Ultimately, the terminology that is frequently used to refer to LX and related concepts in our field lacks semantic clarity, thereby complicating attempts to draw comparisons and build upon prior results.

Secondly, although learning designers are applying methods and processes of UCD in their design contexts, there are as of yet no guidelines for this in LIDT. This is in stark contrast to HCI or sociotechnical systems' design, wherein design principles can be found in abundance. Bridging this research-to-practice gap is critical to assist designers in the

selection and application of methods that are germane to their design goals, appropriate for a given design phase, and resonant with intended design outcomes. For example, learning designers might consider having participants complete a usability questionnaire at the end of a design cycle. While this could yield a positive score in regards to a learning technology's ease of use, ultimately it could have a deleterious effect on ongoing design refinements. Even though usability evaluation can result in a positive technological quality index—which is a necessary quality indicator—this is insufficient for an active, learner-centered learning design. LX design also requires additional quality indicators such as pedagogical usability and sociocultural considerations (discussed in depth by Jahnke, Schmidt, Pham, & Singh in this volume). Usability studies are useful to add to LX studies and should be performed to shed light on effectiveness, efficiency and appeal of learning (Honebein & Honebein, 2015), learner behavior, and on improvement of learning opportunities. However, positive usability scores alone are not particularly helpful because they could end the improvement cycle and could lead stakeholders to false conclusions. Guidelines are needed for aligning and mapping the methods and processes of UCD onto established LIDT design processes.

Thirdly, LX as an emerging area of research and practice has made neither substantial nor sufficient connections to the theoretical foundations of LIDT. How do the methods and processes of UCD align with how we explain, predict, and understand learning, and how do they potentially challenge and extend our existing knowledge? LIDT is inherently interdisciplinary, so it is unsurprising that theories born in the field of HCI have found resonance in our field, such as distributed cognition and activity theory. However, sharing a theoretical lens falls short of establishing a theoretical foundation upon which a tradition can build. Further work is needed that considers guiding philosophical orientations and seeks alignments on a fundamental level.

These issues—lack of semantic clarity, inadequate methodological guidelines, and insufficient theoretical grounding—represent the three major, most troublesome issues but are only a fraction of the challenges that face those interested in LX. Serious attention to these foundational issues is necessary if LX ever is to transcend the collective canon of the LIDT tradition. To our knowledge, no such efforts have been made to-date; hence, there is a need for additional investigation with a book like this.

1.2. Why Open Access?

We chose to publish this book as open access because this publication model lacks many of the barriers of traditional publication models while also presenting unique opportunities for authors and readers. Using open access, barriers such as cost, ability to access, and ability to share are largely obviated. Anyone, anywhere can freely access and share any of the materials in this edited volume at no cost (as long as authors are credited). The open access model allows this work to take on a life of its own and to continue to be developed beyond the date of publication. These unique opportunities rest on the foundation of an important set of permissions that perhaps have been best articulated in our own field in the work spearheaded by David Wiley and his colleagues (Hilton III et al., 2010; Wiley et al., 2014). These permissions are referred to as the "four R's" of open educational resources and are made possible through the use of Creative Commons licensing. As outlined below, and on the condition that authors are appropriately credited, readers of this volume are granted permission to:

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2. Inside This Edited Volume

This edited volume is composed of 16 unique contributions that were developed altogether by a total of 40 authors. All chapters were vetted using a rigorous peer-review process. Initially, all author submissions were closely reviewed by the editors who provided detailed feedback. After revisions were made by the authors, chapters were sent out for peer review. Each chapter was reviewed by at least two different authors who also have a chapter published in this volume. Based on peer review feedback, authors revised their chapters a second time. Each of these revised chapters was again reviewed by the editors before making a final decision to accept a chapter for inclusion in the edited volume. Authors of accepted chapters were then asked to make final revisions. After authors incorporated final revisions, chapter manuscripts were sent out for professional copy editing and reviewed one final time by the authors and editors before being released for publication.

Upon review of the final chapters, authors' work fell fairly evenly into the following four categories:

1. Introduction (this),
2. Methods, paradigms, and theories of LX design (5 chapters),
3. Models and design frameworks for LX (6 chapters), and
4. LX design-in-use (4 chapters).

The chapters that fall within these categories are presented in the following three sections. Each chapter is briefly summarized, with its importance to readers of this volume then being briefly highlighted.

2.1. Methods, Paradigms, and Theories of LX Design

This edited volume begins with six chapters representing an assortment of perspectives on methods, paradigms, and theories related to LX design. The chapters in this section illustrate how theories and methods that have found resonance elsewhere could be applied advantageously in LX. These contributions add to a growing repository of theoretical and methodological foundations for LX and advance our understanding of how these might be applied practically in LX design.

The entry point for this section is a chapter that focuses on methods. Entitled, *Methods of User Centered Design and Evaluation for Learning Designers*, authors Schmidt, Earnshaw, Tawfik, and Jahnke highlight the importance of not only referencing theory in learning design, but also of creating positive and enjoyable learner experiences. To this end, the authors situate their work in theories commonly referenced in LIDT and present with detail a broad range of methods and processes frequently used in user-centered design that can be productively applied in LIDT (e.g., personas, scenarios, prototyping, usability testing). Helpful examples of how to apply these methods and processes in learning design contexts are provided. This work contributes to our understanding of important theories at the intersection of HCI and LIDT and establishes a repertoire of useful methods and processes to guide burgeoning learning designers seeking to engage in learner-centered design and research.

The next chapter in this section, Gray's *Paradigms of Knowledge Production in Human-Computer Interaction: Towards a Framing for Learner Experience (LX) Design*, conceives of LX design as an emerging, transdisciplinary field that incorporates perspectives of HCI, UX, and LIDT. Gray positions HCI knowledge as foundational to UX before synthesizing the historical and conceptual alignment of paradigms, waves, and theoretical approaches in HCI. Recognizing that research in the field of LIDT largely has been isolated from HCI, Gray juxtaposes the LIDT community's tendency to focus on design processes with the HCI community's focus on design methods. To pursue connections between the two fields, Gray attempts to align LIDT processes with HCI and UX methods and concepts (i.e., personas, prototyping, usability testing, etc.). Building on identified gaps in LDT and HCI/UX, Gray proposes a set of guiding principles for shaping the field of LX design. Importantly, this work contributes to our understanding of the relationship between LIDT, HCI/UX, and LX design and calls attention to areas critically in need of further research.

Following this is a chapter that foregrounds the crucial importance in LX of connecting theory with design and evaluating not only hedonic and perceptual dimensions of designed solutions, but also learning impact. In their chapter

Theories of Change in Learning Experience (LX) Design, authors Bowen, Forssell, and Rosier connect theory at a meta-level with LX methods and processes through the application of theories of change. Recognizing the parallels between UX and LX, the authors highlight important distinctions between the two. Both are guided by theory, yet generally draw from different traditions. Specifically, UX design is based on user research, whereas LX design focuses on how people learn. In acknowledgement of the centrality of learning in LX, the authors present theories of change as a sort of epistemic lodestone to guide evolving LX designs. Importantly, the authors stress the necessity of testing underlying hypotheses to validate learning theories and UX factors that support specific design solutions. To illustrate, the authors present two digital learning tools design cases that were guided by theories of change. This approachable confluence of theory and practice from Bowen and his colleagues provides an actionable framework for applying and testing theory as designerly practice.

Flow Theory and Learning Experience Design in Gamified Learning Environments by Vann and Tawfik acknowledges the vital role of theory in learning design, but cautions that privileging theory over considerations of LX can lead to the emergence of unforeseen design flaws. The authors therefore position flow theory as a means not only to describe underlying processes of learning but also to take into account considerations of LX. Following a brief introduction to flow theory, the authors describe how dimensions of flow theory might be linked to learning design. A review of prior studies that apply flow theory in gamified learning contexts is provided. Further, Vann and Tawfik describe the redesign of a gamified online professional development course for university faculty to facilitate the understanding of flow theory in learning design practice. Using the design case approach, the authors describe designed gamification elements and make explicit connections to flow theory while remaining cognizant of corresponding learning experiences.

Rounding out this section is Kimmons' *Color Theory in Experience Design*, a chapter that considers an aspect of design that is rarely discussed by professionals in systematic ways outside the visual arts—color. Kimmons presents color from the perspective of affect and its potential role in influencing intrinsic motivation. The author then provides an in-depth overview of color theory, from the physics of color to color notation to how color is digitally represented in terms of hue, saturation, and brightness. Kimmons links color theory to UX and LX by considering those aspects of color that influence human emotion and how designers might consider color-use within this frame. The author presents useful heuristics to guide selection and use of color LX design, including attending to contrast, attention, meaning, and harmony. This chapter stands apart as an application of visual design theory as applied in LX design practice, contributes to our understanding of how diverse disciplines contribute to LX, and delightfully illustrates the multiple competencies required of LX designers.

2.2. Models and Design Frameworks for LX

The second section of this edited volume includes six chapters exploring an assortment of models and design frameworks for LX. Drawing from a broad spectrum of views and approaches, authors in this section grapple with a range of issues relevant to conceptually grounding individual approaches and informing their design processes. Collectively, these frameworks begin to unveil the preliminary gestalt of LX as a focus area beginning to emerge in LIDT.

The section begins with *Sociotechnical-Pedagogical Usability for Evaluating Learner Experience in Technology-Enhanced Learning Environments*, a chapter by authors Jahnke, Schmidt, Pham, and Singh that claims technological usability evaluation alone is insufficient to account for the multiplicity of perspectives learning designers must consider when seeking to perform usability research on learning technologies. Although research in the field of learning design has increasingly applied methods from usability and UX research for evaluating and improving LX with learning technologies, the authors argue that learning designers must not only consider the technological dimension of usability, but also the pedagogical and social dimensions. To operationalize the framework, the authors present a literature review of 13 articles published since 2006 that provide associated evaluation criteria. On the basis of these prior studies, the authors propose a conceptual framework for *sociotechnical-pedagogical usability*. A diagram illustrates intersections and relationships of the three dimensions with detailed explanations. The chapter concludes with a set of sociotechnical-pedigogical usability design recommendations for hybrid or online courses. This chapter situates usability as a useful evaluation method for LX while at the same time extending and refining underlying principles to better align with learning design.

The chapter *Learning Experience Design: Challenges for Novice Designers* follows with a conceptual design process that positions LX design as an ill-structured problem-solving activity, especially when comparing novice and expert designers. Authors Chang and Kuwata present LX design as a confluence of four interrelated factors, including: (a) learning experience, (b) human-centeredness, (c) goal-orientation, and (d) design. On this basis, the authors present a conceptual design process intended to guide LX design practice, including problem generation, problem-solving process, and solution generation. Chang and Kuwata illustrate this process with an engaging, graphic novel-like LX design scenario that effectively juxtaposes novice and expert design approaches. Several practical suggestions are provided for novice learning designers. While this chapter's relatable style will likely capture readers' attention, the authors' ability to locate LX within established theoretical and procedural traditions of our field will truly resonate.

In a nod to well-established practices of instructional design (ID), authors Stefaniak and Sentz position needs assessment as a way to validate contextual factors in user experience design practice so as to promote learning transfer. Their chapter, *The Role of Needs Assessment to Validate Contextual Factors Related to User Experience Design Practices*, situates UX design practice in the context of instructional design with the goals of facilitating learning and improving performance. These authors promote a systems approach to UX design, maintaining that learning environments are open and therefore complex systems, which underscores (a) the importance of contextual analysis to understand learners' work practice and (b) needs assessment to identify, classify, and validate learner needs relative to work practices. The authors argue that typical approaches to needs assessment are narrow—often only focusing on learner analysis—and fail to conceive of learners as users, which could lead to overlooking important contextual factors that could impact learners. To that end, the authors present a framework to leverage needs assessment outcomes within UX design, including detailed explanations for each element and their relationships. A family of heuristics is provided to help learning designers apply the proposed framework. Firmly rooted in the orthodox traditions of LIDT, this chapter illuminates novel ways to approach established methods.

In the next chapter, *The Design Implementation Framework: Guiding Principles for the Redesign of a Reading Comprehension Intelligent Tutoring System,* authors McCarthy, Watanabe, and McNamara introduce the Design Implementation Framework (DIF) as a means to guide the design and UX of intelligent tutoring systems (ITSs). The authors argue balancing ease-of-use, enjoyment, and efficacy in good ITS design can be achieved by applying the five cyclical phases of the DIF, which include: (a) defining and evaluating the problem, (b) ideation, (c) design and user experience, (d) experimental evaluations, and (e) feedback and implementation. A case study is presented, illustrating the DIF in practice and highlighting the variable nature of the process across various design contexts. The authors describe methods and outcomes of each phase and how adjustments should be made in accord with evolving design conditions. As the chapter progresses, the authors also underscore the importance of evaluation to the DIF for driving design changes. Observant readers will take heed not only of the authors' well-articulated design framework, but also their deft ability to flexibly enhance their approach through data-based decision-making—arguably a skill of the superior designer.

In the chapter *From Engagement to User Experience: A Theoretical Perspective Towards Immersive Learning*, authors Oprean and Balakrishnan present a conceptual design framework blending immersive technology and user/learner experience to impact learner engagement. The authors present various attributes of immersive technologies, including virtual reality (VR), augmented reality (AR), and mixed reality. To bridge technology and outcomes, Oprean and Balakrishnan then propose a framework that describes the role of UX in designing immersive technology to promote intended learning outcomes. The authors present concepts of immersive learning and UX factors as central to amplifying perceptions of presence, embodiment, engagement, and novelty. These, in turn, influence learner engagement. The authors provide examples in which they apply immersive technologies aimed at enhancing learner engagement, concluding that their immersive framework could promote better understanding of the immersive technology attributes that might impact learner engagement.

Concluding this section is a chapter presenting an LX-focused workflow for the systematic design of physical—not digital—game-based learning interventions. Abbott's *Intentional Learning Design for Educational Games: A Workflow Supporting Novices and Experts* synthesizes a set of LX design principles and links each principle to characteristics of

game-based learning. The chapter then proposes a mapping of common weaknesses in GBL to potential LXD-informed improvements. Abbott further proposes a guided workflow for developing effective and learner-centered educational games, consisting of four groups of overlapping design activities with various foci, including ID, empathy/emotional design, interaction design, and game design. Abbott elaborates on each step of this workflow with a design case. Applying LX design principles to a game design process ensures the connection between appropriate pedagogical foundations and the needs and desires of learners. Abbott's masterful ability to meaningfully situate LX within a multitude of complex and competing design processes is a particular highlight of this section. The chapter's focus on physical games provides a fresh perspective that even the most seasoned designer surely will appreciate.

2.3. LX Design-in-Use

The third and final section of this edited volume consists of four chapters that relay cases of LX design-in-use. By design-in-use, we refer to the applied use of LX methods and processes to create digital environments for learning. These chapters serve as exemplars on multiple levels. On one level, they represent worked examples that detail the actions, events, rationales, challenges, etc. of LX design from beginning to end. On another level, the chapters are success cases of LX design, highlighting the synergistic interplay of pedagogy and theory with perceptions of usefulness and other hedonic aspects.

Beginning this section is Quintana, Haley, Magyar and Tan's *Integrating Learner and User Experience Design: A Bidirectional Approach*, in which the authors present their vision for learning design as a bidirectional interplay between UX designers and LX designers. To support their bidirectional approach, the authors foreground the complexities introduced to the design process as a result of conceiving of learners as users. A balance between UX and LX can be struck when designers consider operational tasks from the UX perspective and learning tasks from the LX perspective. The authors introduce a heuristic "learning with software" approach to evaluating learning tools, which adapts known usability heuristics to a range of learning-related factors. Quintana and her colleagues then present two design cases that feature this approach to learning design, with distinct contributions from both UX and LX perspectives. The first design case illustrates how UX designers took on a primary role, with support from LX designers to identify learners' concerns, examine features from the perspective of learning tasks, and provide feedback on design outcomes at various stages. The second case demonstrates how a learning activity was designed and implemented by LX designers to guide instructors through the development of learner personas (a well-known approach within UX design processes). The authors conclude their chapter with helpful principles for guiding LX/UX collaborations. Their work not only illustrates how UX and LX can be combined synergistically, but also serves as encouragement for burgeoning learning designers who may be intimidated by the perhaps overwhelming breadth of knowledge, skills, and design acumen subsumed in LX design. With careful planning, learning designers can work in tandem with UX designers to create effective and pleasing designs.

In the chapter *Participatory Design and Co-design—the Case of a MOOC on Public Innovation*, authors Cavignaux-Bros and Cristol present a case that applies participatory design and co-design methods to the design of a Massive Open Online Course (MOOC). As a primary thrust of the chapter, the authors detail how they implemented co-design across three stages of their timeline and participatory design in a fourth and final design stage prior to launch. Explanations are provided of the activities conducted in each design stage, along with figures illustrating the deliverables created by the participants. The outcomes of the participatory design and co-design case are presented from two perspectives. One is the final production of the course, which is reported to have positively influenced the number of enrollments; the other is the reflections on LX design as a professional development outcome of the design teams. By focusing on participatory design and co-design as potentially useful methods for instructional designers and user experience (UX) designers, these authors provide useful insight into methods that historically have been overlooked in LIDT.

The case presented by Raza, Penuel, Jacobs, and Sumner, *Supporting Equity in Schools: Using Visual Learning Analytics to Understand Learners' Classroom Experiences*, serves as an application of UX design methods to the design of a visual learning analytics dashboard for teachers to promote equitable instruction at the classroom level. Couched in relevant literature, the authors provide justification for the use of data-driven decision making in schools and how equitable instruction may be supported through three key constructs: coherence, relevance, and contribution. The

authors present a design conjecture that contends LA dashboards that embody these constructs could promote equity for diverse student populations by supporting teachers' data-based decision-making. They then elaborate on how think-aloud and cognitive interview methods supported the design of their LA dashboards. Their work illustrates the application of established UX methods in the design of an instructional technology intended to enhance desired classroom experiences. This work contributes to our understanding of the multiplicity and complexity of LX, which extends beyond learners to be inclusive of instructors as well.

This section concludes with the chapter *Think-Aloud Observations to Improve Online Course Design: A Case Example and "How-to" Guide* by Gregg, Reid, Aldemir, Gray, Frederick, and Garbrick. These authors present a case that uses think-aloud observations (TAO) methods to explore the perceived UX of online course designs within a learning management system (LMS). On the basis of Dewey's transactional theory of knowing, the authors present UX as the intersection of learner experience and pedagogical usability. In addition to the goal of making LMS courses easier to navigate, the authors also identify UX design principles and methods that could be used as references for others in the field. The authors explain their design case with great detail using their data collection, data analysis, and findings. Five design principles for maximizing the UX of online courses offered within an LMS are provided: (a) avoid naming ambiguities, (b) minimize multiple interfaces, (c) design within the conventions of the LMS, (d) group related information together, and (e) consider establishing consistent design standards throughout the university. Drawing from prior literature and self-reflections, the authors provide steps for others to conduct a TAO study. Their work illustrates UX testing methods applied to learning design and contributes to our understanding of how to conduct a TAO method to both enhance a learning design and contribute to the general knowledge base of the field.

3. Discussion

Having reviewed the unique contributions of the various authors and author teams, our attention now shifts to a more integrative perspective. What interpretations might we draw from the collection of diverse perspectives presented here? Our experiences as editors in overseeing the development of this volume certainly have led to a number of unique insights into the character of the LX phenomenon, which we proffer as three overarching axia below and discuss in the following sections:

1. Axiom of Transdisciplinarity: Although LX represents a confluence of many fields, it emerges as palpably distinct. It is intrinsically and inextricably transdisciplinary, is heavily influenced by UX design, and has particularly deep roots in LIDT.
2. Axiom of Complexity: Complexity is central to the LX phenomenon. LX is not only concerned with the effectiveness of designed learning interventions, but also with the interconnected and interdependent relationship between the learner-as-user, the designed intervention, and the learning context.
3. Axiom of Multiple Literacies: Accepting LX as a transdisciplinary and complex phenomenon implies that multiple literacies are therefore intrinsic to LX design. By extension, an extensive repertoire of knowledge, skills, and abilities across a range of disciplines is imperative.

3.1. Axiom of Transdisciplinarity

To situate LX as transdisciplinary suggests that it must first be distinguished from terms such as *multidisciplinary* and *interdisciplinary*. To this end, we draw from Choi and Pak's (2006) frequently cited paper in which they rigorously define these terms. Firstly, the term *multidisciplinary* involves various disciplines seeking to achieve a common aim; however, contributions remain distinct and interactions tend to be largely siloed. A great deal of instructional design (ID) projects can be described as multidisciplinary. ID projects in which subject matter experts provide content expertise and instructional designers segment and sequence the content in such a way as to promote identified learning objectives exemplify multiple disciplines contributing to a common goal, but their efforts are not integrated or tightly coordinated. Secondly, the term *interdisciplinary* refers to the combination of and interaction between two or more disciplines towards a common aim, the result of which is so closely interwoven that it is not possible to distinguish the discipline from which any given contribution was made. An example from the field of LIDT would be from the methodological

approach referred to as educational design research (EDR—also known as design-based research; cf. McKenney & Reeves, 2018). EDR advocates for establishing seamless collaborations between researchers and practitioners to facilitate efficient establishment, communication, and implementation of design solutions so as to facilitate educational impact. While the inputs of EDR that lead to designed solutions come from distinct traditions of research and practice, the final outcome cannot be attributed to any single discipline. Third and finally, we turn to the term *transdisciplinary*. This approach tightly integrates perspectives of multiple disciplines (as does interdisciplinarity) but also transcends them, which can lead to the emergence of entirely new knowledge. Given the nature of transdisciplinarity, it is therefore not possible to find an example inside the field of LIDT; however, examples can be found in disciplines outside of our own that have integrated aspects of LIDT to create something entirely new. A particularly recognizable transdisciplinary discipline can be found in the field of learning sciences. Learning sciences is a confluence of many fields, including philosophy, neuroscience, linguistics, educational technology, information science, etc. While each of these fields certainly makes its own contributions, the focus and methods of the learning sciences to advance the scientific understanding of learning transcend those of any single field.

Similarly, LX represents a confluence of many fields, including HCI, information technology, education, learning and instructional design, educational technology, psychology, etc. While individual contributions from those fields are evident in LX, the manner in which those contributions manifest and their intended outcomes are distinct. For example, usability testing is perhaps the most recognizable user research method of UX. This method is also widely used in LX. However, the manner in which it is applied and to what ends is distinct. LX usability not only considers the technological usability of a given learning technology, but also the influence of pedagogical and social factors. Further, LX usability's concept of the user is multifaceted, shaped by considerations of technology usage as well as considerations of learning. Moreover, LX necessarily requires a broad interpretation of context, including not only the immediate physical context but also sociocultural factors that could impact learning. The outcomes of LX usability transcend the bounds of merely improving the design of learning technologies, concomitantly informing our theoretical understanding of how people learn with and through learning technologies. While the additive and interactive aspects of multi- and interdisciplinarity are evident in this example, the more holistic nature of the approach serves to illustrate how LX can go beyond the traditional bounds of contributing disciplines. In the current volume, the transdisciplinary character of LX is particularly well represented in Gray's *Paradigms* chapter and Jahnke and colleagues *Socio-technical Pedagogical Usability* chapter.

3.2. Axiom of Complexity

We argue that LX is an emergent property of a complex, interconnected and interdependent system that includes, but is not limited to, the designed intervention, learner-as-user, and learning context. To situate LX within the frame of complexity, we turn to complexity theory. Complexity finds its roots in chaos theory and has found a limited foothold in the field of LIDT (e.g., Jacobson & Kapur, 2012; Jonassen, 2000; Reigeluth, 2004). Complexity theory eschews deterministic and causal models of predictability, instead adopting a more organic, holistic, and non-linear perspective. Particularly relevant to LX are the complex system properties of dynamics and emergence.

Complex systems are comprised of many component parts that themselves can be simple. What leads these systems to be complex are the connections and dependencies between the system components, which all interact in a non-linear manner. On a small scale, causal inferences can be made regarding the interactions between system components; however, this becomes impossible at a large scale. How the system behaves cannot be predicted by considering the component parts. Instead, behavior is determined by the dynamic nature of interaction between interconnected and interdependent component parts. However, the system's behavior is also dependent upon its context or environment. Therefore, the system's behavior emerges from a complex interplay of dynamic interactions and context.

The properties of complex systems also can be applied to describe the phenomenon of LX. With the understanding that any attempt to describe a complex system is inherently reductive, many component parts can easily be identified that contribute to LX, such as the tools that comprise the designed intervention (e.g., networks, computers, software, operating systems, user interfaces), the pedagogical strategies employed (e.g., instructions. sequencing, scaffolding),

the learner-as-user (e.g., elementary student, journeyman carpenter, marketing trainee), and so-on. Further, the contexts within which these component parts are situated contribute, such as the social context (e.g., university course, corporate training, high school homeschooling), the nature of the social context, (e.g., formal, informal), and sociocultural factors influencing the social context (e.g., communication norms, social mores, shared values, native language). No single factor in this complex ecosystem individually affects learning; instead, it is the nature of interaction between these components that gives rise to the phenomenon of learning as an individually perceived, unique experience. This individual experience could therefore be described as an emergent property of a complex system. Readers can find a particularly apt representation of complexity in LX in the current volume in Abbott's *Intentional Learning Design for Educational Games*.

3.3. Axiom of Multiple Literacies

Assuming for the purpose of argument that the transdisciplinarity and complexity conjectures proffered above are not false, it follows that a vast array of corresponding knowledge, skills, and abilities that draw from a range of disciplines is needed. A potential implication of this could be that the level of expertise required to engage in LX research and practice is so formidable that it is simply not feasible. However, while LX design indeed does require multiple literacies, instructional and learning designers do not necessarily need to individually master all of the multiple literacies of LX. Instead, LX designers should strive to establish methods and processes to productively collaborate with others from contributing disciplines (e.g., HCI experts, UX designers, interface designers, etc.).

The prospect of instructional designers and/or LX designers collaborating with contributing disciplines, for example by using participatory and co-design methods, presents opportunities for powerful synergy. This could lead to improved outcomes along at least two dimensions: (a) enhancement of the general LX for learners-as-end-users and (b) promotion of professional development for all members of a design team (e.g., project managers, training consultants, and instructional designers). In this manner, LX design—as a participatory or co-design approach—could potentially serve as a method for professional development of educators. This prospect echoes conclusions from other areas of our field. Indeed, Voogt and colleagues (2015) highlight the situative and generative nature of such collaborations as being particularly conducive to professional development. Further, scholars in the area of educational game design (e.g., Charsky, 2010; Hirumi et al., 2010a, 2010b; Van Eck et al., 2017) have recognized that the multiple literacies required in game design would be impossible for learning designers to reasonably master. Therefore, establishing productive methods and processes of collaborating with game developers is recommended. Specifically, "[T]he ID person must be an advocate for appropriate learning experiences throughout the entire process and work with those advocates involving different areas of development, such as the functionality, the delivery, and the affective components of the form itself" (Hirumi et al., 2010b, p. 23). Readers are specifically referred to Quintana and colleagues' *Integrating Learner and User Experience Design* chapter and Cavignaux-Bros and Cristol's *Participatory Design and Co-design* chapters in this volume for examples of productive LX approaches that integrate multiple literacies across disciplines.

4. Conclusion

The body of scholarship in this edited volume represents a significant step towards firmly and formally establishing LX within the tradition of LIDT. Although LX is an embryonic and emerging area of focus in our field, the broad and diverse perspectives presented in this volume represent remarkable maturity, intellectual rigor, and scholarly merit. To be sure, researchers have been engaged in productive scholarly endeavors at the intersection of learning design, UX, HCI, and associated disciplines for some time (e.g., Boling et al., 2015; Moore et al., 2014; Nokelainen, 2006; Schmidt, 2014; Tawfik et al., 2018). Our work as editors has sought to capture and disseminate the collective voices of authors working in this area within a single volume. Adopting the metaphor of cartography, the vibrant diversity and breadth of perspectives presented herein serve as a topographical sketch of the emerging focus area of LX; however, far more work is needed to fully map the landscape.

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Methods, Paradigms, and Theories of LX Design

This section consists of five chapters representing an assortment of perspectives on methods, paradigms, and theories related to LX design. The chapters in this section illustrate how theories and methods that have found resonance elsewhere could be applied advantageously in LX. These contributions add to a growing repository of theoretical and methodological foundations for LX and advance our understanding of how these might be applied practically in LX design.

Methods of User Centered Design and Evaluation for Learning Designers
Paradigms of Knowledge Production in Human-Computer Interaction: Towards a Framing for Learner Experience (LX) Design
Theories of Change in Learning Experience (LX) Design
Flow Theory and Learning Experience Design in Gamified Learning Environments
Color Theory in Experience Design

Methods of User Centered Design and Evaluation for Learning Designers

Matthew Schmidt, Yvonne Earnshaw, Andrew A. Tawfik, & Isa Jahnke

| User Experience | User-centered Design | Human-computer Interaction | Learning Design | Evaluation Methods |

Various theories and models have been published that guide the design and development of learning technologies. While these approaches can be useful for promoting cognitive or affective learning outcomes, user-centered design methods and processes from the field of human-computer interaction (HCI) can also be of value to those in the learning design and instructional design and technology (LIDT) community. In this chapter, we present user-centered design, development, evaluation methods, and processes derived from HCI that lead to highly usable technologies promoting positive user experiences. We begin by aligning these methods and processes with theories commonly referenced in the field of LIDT. We then outline specific methodologies that can be applied during the design and development of digital learning environments. The detailed descriptions outline the goals of the various methods and the ideal stage in which to apply the methods; theory and practice are also discussed. Multiple case examples illustrating how the methods can be used in practice are provided.

Editor's Note

A previous version of this chapter was included in a prior publication (cited below). The current version extends on the previous version by providing examples relevant to the field of Learning/Instructional Design, further clarifications, and additional illustrative figures.

Earnshaw, Y., Tawfik, A., & Schmidt, M. (2017). User experience design. In R. E. West (Ed.), *Foundations of learning and instructional design technology* (1st ed.). EdTech Books. https://edtechbooks.org/-ENoi

1. Introduction

Educators and learners are increasingly reliant on digital tools to facilitate learning. However, educators and learners often use technology in ways that are different than developers originally intended (Straub, 2017). For instance, educators may be faced with challenges trying to determine how to assess student learning in their learning management system (LMS), so they use a different tool and then copy/paste the results. Or they might spend time

determining workarounds to administer lesson plans because the LMS does not directly support a particular pedagogical approach. From the perspective of learners, experiencing challenges navigating an interface or finding homework details might result in frustration or even missed assignments. When an interface is not easy to use, users tend to develop alternative paths to complete a task to accomplish a learning goal. Long recognized in the field of human-computer interaction (HCI), such adjustments, accommodations, and improvisations are the result of design flaws (cf. Orlikowski, 1990; Grudin, 1988). These design flaws are often the result of the software development team failing to consider the user sufficiently in the design process. This extends to the field of learning design and instructional design and technology (collectively LIDT) and can create barriers to effective instruction (Jou et al., 2016; Rodríguez et al., 2017). Increasingly, user-centered approaches to design are being accepted as particularly useful in supporting positive user experience. User-centered design (UCD) emphasizes understanding users' needs and expectations throughout all phases of design (Norman, 1986).

Understanding how educators and learners interact with learning technologies is key to avoiding and remediating design flaws. HCI seeks to understand the interaction between technology and the people who use it from multiple perspectives (Rogers, 2012)—two of which are user experience (UX) and usability. UX describes the broader context of technology usage in terms of "a person's perceptions and responses that result from the use or anticipated use of a product, system, or service" (International Organization for Standardization, 2010, Terms and Definitions section, para 2.15). UX considers all aspects of a user's interaction with technology, including how pleasing and usable the technology is. More specifically, usability describes how easy or difficult it is for users to interact with a user interface in the manner intended by the software developer (Nielsen, 2012). Highly usable user interfaces are easy for users to become familiar with, support users achieving their goals, and are easy to remember. From the perspective of learning design, these design factors are used strategically to focus cognitive resources primarily on the task of learning.

The principles of HCI and UCD have implications for the design of learning environments. While the field of LIDT has focused historically on theories that guide learning design (e.g., scaffolding, sociocultural theory), less emphasis has been placed on learning technology design from the view of HCI and UCD (Okumuş et al., 2016). This chapter addresses this issue. We begin with a discussion of some of the theories used in the field of LIDT that align with UX. We then discuss the importance of iteration in design cycles and provide implications with details of UCD-specific methodologies that allow learning designers to approach design from both pedagogical and HCI perspectives. Multiple case examples drawn from the authors' real-world experiences are provided, illustrating how this can be enacted in practice. The intention of this chapter is to highlight how the fields of HCI and LIDT can intersect synergistically by aligning theories and design approaches of LIDT with methods and processes more commonly used in the field of HCI.

2. Theoretical Foundations

Usability and HCI are often situated in established theories such as cognitive load theory, distributed cognition, and activity theory. LIDT is a sister of these disciplines; hence, these theories also have ramifications for the design and development of learning technologies. In the following sections, we discuss each theory and the importance of conceptualizing UCD, usability, and UX from the LIDT perspective.

2.1. Cognitive Load Theory

Cognitive load theory (CLT) contends that learning is predicated on effective cognitive processing; however, an individual only has a limited number of resources needed to process the information (Mayer & Moreno, 2003; Paas & Ayres, 2014). The three categories of CLT include: (a) intrinsic load, (b) extraneous load, and (c) germane load (Sweller et al., 1998). Firstly, intrinsic load describes the active processing or holding of verbal and visual representations within working memory. Secondly, extraneous load includes the elements that are not essential for learning but are still present for learners to process (Korbach et al., 2017). Thirdly, germane load describes the relevant load imposed by the effective instructional/learning design of learning materials (hereafter referred to simply as learning design). Germane cognitive load is therefore relevant to schema construction as information is subsumed into long-term memory (Paas et al., 2003; Sweller et al., 1998; van Merriënboer & Ayres, 2005). It is important to note that the elements of CLT are

additive, meaning that, if learning is to occur, the total load cannot exceed available working memory resources (Paas et al., 2003).

Extraneous load is of particular importance for UCD. Extraneous cognitive load can be directly manipulated by a designer (van Merriënboer & Ayres, 2005) through improved usability. When an interface is not designed with usability in mind, the extraneous cognitive load is increased, which impedes meaningful learning. From a learning design perspective, poor usability might result in extraneous cognitive load in many forms. For instance, a poor navigation structure in an online course might require the learner to extend extra effort to click through the learning modules to find relevant information. Further, when an instructor uses unfamiliar terms in digital learning materials that do not align with a learners's mental model or the different web pages in a learning module are not consistently designed, the learner must exert additional effort toward understanding the materials. Another example of extraneous cognitive load is when a learner does not know how to progress in a digital learning environment, resulting in an interruption of learning flow. Although there are many other examples, each depicts how poor usability taxes finite cognitive resources. Creating highly usable digital environments for learning can help reduce extraneous cognitive load and allow mental resources to remain focused on germane cognitive load for building schemas (Sweller et al., 1998).

2.2. Distributed Cognition and Activity Theory

While cognitive load theory helps describe the individual experience of user actions and interactions, other theories and models focus on broader conceptualizations of HCI. Among the most prominent are distributed cognition and activity theory, which take into account the broader context of learning and introduce the role of collaboration between various individuals. Distributed cognition postulates that knowledge is present both within the mind of an individual and across artifacts (Hollan et al., 2000). The theory focuses on the understanding of the coordination "among individuals and artifacts, that is, to understand how individual agents align and share within a distributed process" (Nardi, 1996, p. 39). From the perspective of LIDT, individual agents (e.g., learners, instructors) operate within a distributed process of learning, as facilitated by various artifacts (such as content, messages, and media). The distributed process of learning is mediated by intentional interaction and communication with learning technologies (e.g., learning management systems, web conferencing platforms) in pursuit of learning objectives (Boland et al., 1994; Vasiliou et al., 2014). For example, two learners collaborating on a pair of programming problems might write pseudo-code and input comments into a text editor. In this case, distributed cognition is evident in collaborating on the programming problem and by conceptualizing various solutions mentally but also by using a tool (the text editor) to extend their memory. Cognition in this case is distributed between people and tools; distributed cognition, therefore, would focus on the function of the tool within the broader learning context (Michaelian & Sutton, 2013). In contrast with the more narrow perspective of cognitive load theory that considers the degree to which a specific learner's finite cognitive resources are affected when interacting with a technology system, distributed cognition adopts a broader cognitive, social, and organizational perspective (Rogers, 1997).

Activity theory is a systems-based, ecological framework that shares some similarities with distributed cognition but distinguishes itself in its specific focus on activity and the dynamic interplay of actors, artifacts, and sociocultural factors within an interconnected system. Given its ecological lens, activity theory can be a useful framework for describing and understanding how a variety of factors can influence human activity. Central to activity theory is the concept of mediation. In activity theory, activity is mediated by tools, also called artefacts (Kaptelenin, 1996). From a technological perspective the concept of tools is often in reference to digital tools or software. These technological tools mediate human activity within a goal-directed hierarchy of (a) activities, (b) actions, and (c) operations (Jonassen & Rohrer-Murphy, 1999). Firstly, activities describe the top-level objectives and fulfillment of motives (Kaptelinin et al., 1999). Secondly, actions are the more specific goal-directed processes and smaller tasks that must be completed in order to complete overarching activities. Thirdly, operations describe the automatic cognitive processes that group members complete (Engeström, 2000). However, they do not maintain their own goals but are rather the unconscious adjustment of actions to the situation at hand (Kaptelinin et al., 1999). Engeström's (2000) sociocultural activity theory framework is commonly depicted as an interconnected system in the shape of a triangle, as depicted in Figure 1.
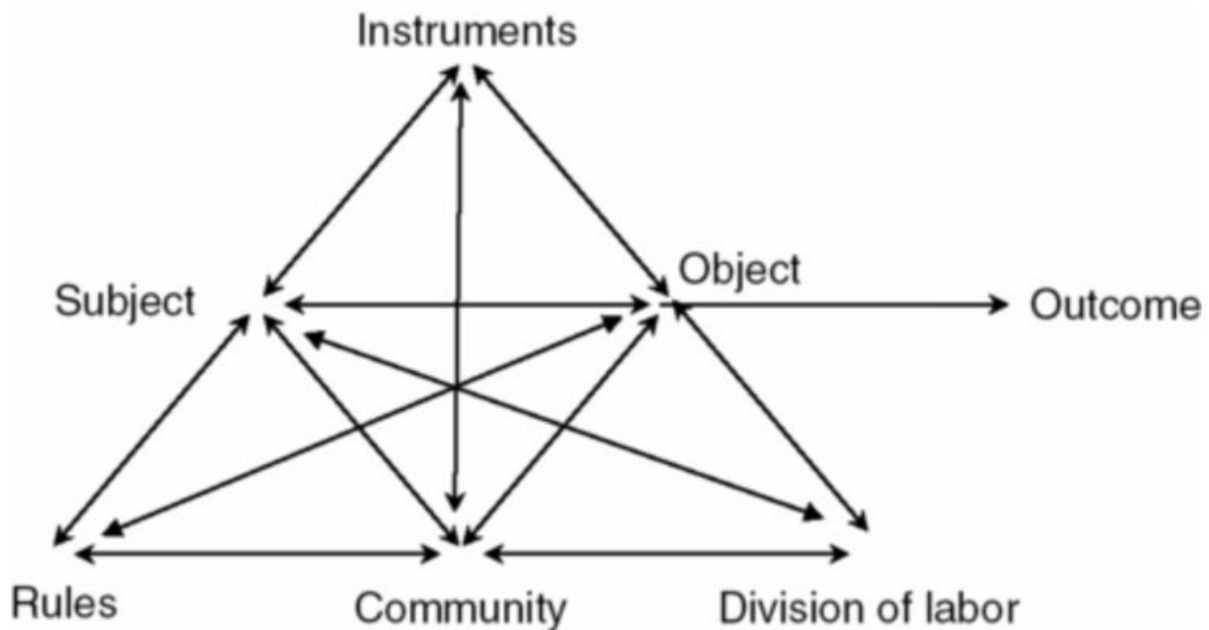
Figure 1

Activity System Diagram

Note. Adapted from Engeström (2000, p. 962).

Activity theory is especially helpful for learning design because it provides a framework to understand how objectives are completed within a learning context. Nardi (1996) highlights the centrality to activity theory of mediation via tools/artefacts. These artefacts are created by individuals to control their own behavior and can manifest in the form of instruments, languages, or technology. Each carries a particular culture and history that stretches across time and space (Kaptelinin et al., 1999) and serves to represent ways in which others have solved similar problems. As applied to learning contexts, activity theory suggests that tools not only mediate the learning experience but that learning processes are often altered to accommodate the new tools (Jonassen & Rohrer-Murphy, 1999). This underscores the importance of considering the influence of novel learning technologies (e.g., LMSs, educational video games) from within a broader context of social activity when implemented by schools and/or organizations (Ackerman, 2000). The technological tools instituted in a particular workgroup should not radically change work processes but should present solutions on the basis of needs, constraints, history, etc. of that workgroup (Barab et al., 2002; Yamagata-Lynch et al., 2015). As learning is increasingly collaborative through technology (particularly online learning), activity theory and distributed cognition can provide important insights for learning designers into the broader sociocultural aspects of human-computer interaction.

3. User-Centered Design

The brief overview of theoretical foundations provided in the above sections highlights how theories of cognition and human activity in sociocultural contexts can be useful in the design of digital environments for learning. However, the question remains as to how one designs highly usable, pleasing, and effective digital environments for learning on the basis of these theories. Answering this question is difficult because these theories are not prescriptive. Specific guidance for how they can be applied is lacking, meaning that how best to design theoretically inspired, highly usable and pleasing learning environments is ultimately the prerogative of the designer. Iterative design approaches can be useful for confronting this conundrum. While the field of LIDT has recently begun to shift its focus to more iterative design and user-driven development models, there is a need to more intentionally bridge learning design and user-

centered design approaches to support positive learner experience in digital environments. To this end, a number of existing learning design methods can be used or adapted to fit iterative approaches. For example, identifying learning needs has long been the focus of front-end analysis. Ideation and prototyping are frequently used methods from UX design and rapid prototyping. Evaluation in learning design has a rich history of formative and summative methods. By applying these specific design methods within iterative design processes, learning designers can advance their designs in such a way that they can focus not only on intended learning outcomes but also on the learner experience and usability of their designs. In the following sections, UCD is considered with a specific focus on techniques for incorporation into one's learning design processes through (a) identifying user needs, (b) requirements gathering, (c) prototyping, and (d) wireframing.

3.1. Developing Requirements Based on Learners' Needs

One potential pitfall of any design process occurs when designers create systems based on assumptions of what users want. Only after designers have begun to understand the user should they begin to identify what capabilities or conditions a system must be able to support to meet the identified needs. These capabilities or conditions are known as requirements. The process a designer undertakes to identify these requirements is known as requirements gathering. Generally, requirements gathering involves gathering and analyzing user data (e.g., surveys, focus groups, interviews, observations) and assessing user needs (Sleezer et al., 2014).

In the field of LIDT, assessing learner needs often begins with identification of a gap (the need) between actual performance and optimal performance (Rossett, 1987; Rossett & Sheldon, 2001). Needs and performance can then be further analyzed and learning interventions designed to address those needs. Assessing user (and learner) needs can yield important information about performance gaps and other problems. However, knowledge of needs alone is insufficient to design highly usable and pleasing learning environments. Further detail is needed regarding the specific context of use for a given tool or system. Context is defined by learners (and others who will use the tool or system such as administrators or instructors), tasks (what will learners do with the tool or system), and environment (the local context in which learners use the tool or system).

Based on identified learner needs, a set of requirements is generated to define what system capabilities must be developed to meet those needs. Requirements are not just obtained for one set of learners but for all learner types and personas (including instructors and administrators) that might utilize the system. Data-based requirements (a) help learning designers avoid the pitfall of applying ready-made solutions to assumed learner needs, (b) position the learner and their needs centrally in the design process, and (c) allow for creation of design guidelines targeting an array of various learner needs. Requirements based on learner data are therefore more promising in supporting a positive learner experience. However, given the iterative nature of UCD, requirements might change as a design evolves. Shifts in requirements vary depending on design and associated evaluation outcomes. Two methods commonly used in UCD for establishing requirements are persona and scenario development.

3.1.1. Personas

In UCD, a popular approach to understanding users is to create what is known as personas (Cooper, 2004). Personas provide a detailed description of a fictional user whose characteristics represent a specific user group. They serve as a methodological tool that helps designers approach design based on the perspective of the user rather than (often biased) assumptions. A persona typically includes information about a user's demographics, goals, needs, typical day, and experiences. In order to create a persona, interviews or observations should gather information from individual users and then place them into specific user categories. Personas should be updated if there are changes to technology, business needs, or other factors. These archetypes help designers obtain a deep understanding of the types of users for the system. Personas are especially helpful for learning designers in considering cultural diversity. Learning design teams tend to be small (2-3 members) or consist of an individual learning designer. Such teams can lack sufficient sociocultural perspective to design for a culturally sensitive and diverse learner experience. However, developing personas of, for example, a 25 year-old African-American woman who is a first generation college student or a 17 year-old, male Asian-American high school student athlete can provide context for designers to consider these

sociocultural perspectives more intentionally in their learning designs. Because learner personas should be developed based on data that have been gathered about those learners, implicit bias can be reduced.

Table 1 provides an example of a culturally-situated persona in the context of Hawaiian public schools that was created by novice designers in an introductory learning design course using a template. The design context was development of a parent-teacher communication portal for public schools throughout the state using the Hawaii Department of Education E-School course management system. This particular persona highlights the value that Hawaiian families tend to place on family and interpersonal relationships.

Table 1

Persona of Parent-Teacher Communication Portal Users

Note. Derived from: http://usabilitybok.org/persona

User Goals: What users are trying to achieve by using your site, such as tasks they want to perform
1. Parents seek advice on improving teacher/parent interactions 2. Parents seek to build and foster a positive partnership between teacher and parents to contribute to child's school success 3. Parents wish to find new ways or improve ways of parent-teacher communication
Behavior: Online and offline behavior patterns, helping to identify users' goals
1. Online behavior: "Googling" ways to improve teacher communication with parent or parent communication with teacher; parent searching parent/teacher communication sites for types of technology to improve communication; navigating through site to reach information 2. Offline behavior: Had ineffective or negative parent-teacher communication over multiple occurrences; parents seeking out other parents for advice or teachers asking colleagues for suggestions to improve communication with parents 3. Online/Offline behavior: Taking notes, practicing strategies or tips suggested, discussing with a colleague or friend.
Attitudes: Relevant attitudes that predict how users will behave
1. Looking for answers 2. Reflective 3. Curiosity-driven
Motivations: Why users want to achieve these goals
1. Wishing to avoid past unpleasant experiences of dealing with parent-teacher interaction 2. Looking to improve current or future parent-teacher relationships 3. Looking to avoid negative perceptions of their child by teacher
Design team objectives: What you ideally want users to accomplish in order to ensure your website is successful?

1. Have an interface that is easy to navigate
2. Inclusion of both parent and teacher in the page (no portal/splash page)
3. Grab interest and engage users to continue reading and exploring the site

3.1.2. Scenarios

A complimentary method to personas is scenarios. Scenarios provide a means to situate the user/learner persona and technology within a realistic context of usage while the learner attempts to achieve his or her goal. Scenarios are presented as narratives that describe user activity in an informal story format (Carroll, 2000). While scenarios are widely used in software development, there is little specific guidance on how they should be developed. Generally speaking, scenarios should be developed in such a way that they are able to provide the designer useful detail about contexts, needs, and goals, which can be used to highlight necessary requirements.

Table 2 provides an example scenario that was created in the context of a virtual reality (VR) learning intervention for youth with autism spectrum disorders. The design target of this scenario was a tool that would allow learners to compare snapshots of their own facial expressions with a standard model inside of the VR world. In this scenario, the learner persona "John" interacts with the teacher persona "Carla" to engage in the task. This scenario illustrates how a scenario helps to illustrate how a learner persona (in this case, John) engages with a learning technology.

Table 2

Scenario of Learner With Autism Using a Virtual Reality Tool to Learn Facial Expressions

Component	Component Description
Context	John is viewing images of faces showing emotions and states including happy, surprised, and disappointed in the collaborative virtual world. His teacher, Carla, has asked him to make a face showing he is sad and share it with the group.
Goal	John's goal is to take a webcam picture of himself using the tools provided in the VR interface and to discuss his picture with his teacher and the rest of his group.
Activity	John learned to use the camera when he was completing his orientation, so he knows how to do this. John tries to make a sad face and snaps his picture using the Live Images application on the heads-up display.
	His picture shows up automatically on a shared media board in the virtual world. John's picture takes up a large portion of the media board, since it is the only picture. Carla and John look at the picture, and then Carla makes a suggestion for how his expression could better show sadness.
	Carla says, "I'll remove this picture and would like you to try again?" She deletes the first image.
	John retakes the image and asks Carla, "Does this face look sad enough?"
	Carla provides positive praise, "I really like how you asked me about your picture!" and continues, "Let's ask the rest of the group."
Outcome	The whole group discusses John's picture and provides their input. After their discussion is over and John has some feedback, he asks if he can try again. Carla deletes his image and John takes another

image to share. After everyone praises John for getting it right this time, Carla deletes John's image and asks Mary to try to show a surprised look.

3.2. Prototyping Digital Environments for Learning

Gathering data to design and develop digital environments for learning is an iterative process. Based on personas and identified requirements, an initial prototype of the user interface or the online learning environment will be created. Prototypes tend to follow a trajectory of development over time from low fidelity to high fidelity (Walker et al., 2002). Fidelity refers to the degree of precision, attention to detail, and functionality of a prototype. Examples range from lower fidelity prototypes, which include the proverbial "sketch on a napkin" and paper prototypes, to higher fidelity prototypes, which include non-functional "dummy" graphical mockups of interfaces and interfaces with limited functionality that allow for evaluation. Typically, lower fidelity prototypes (lo-fi prototypes) do not take much time to develop and higher fidelity prototypes take longer because prototypes become more difficult to change as more details and features are added. Prototyping is a useful skill for all learning designers, including those who create online courses by arranging various content, media, and interactive experiences to those who develop educational software such as educational video games or mobile apps.

3.2.1. Rapid Prototyping

Rapid prototyping is an approach to design that emerged in the 1980s in engineering fields and began to gain traction in instructional design in the early 1990s (Desrosier, 2011; Tripp & Bichelmeyer, 1990; Wilson et al., 1993). Instead of traditional instructional design approaches with lengthy design and development phases, rapid prototyping focuses on fast, or "rapid," iterations. This allows instructional designers to quickly gather evaluative feedback on their early designs. Considered a feedback-driven approach, rapid prototyping is seen by many as a powerful tool for the early stages of a learning design project. The rapid prototyping approach relies on multiple, rapid cycles in which an artifact is designed, developed, tested, and revised. Actual users of the system participate during the testing phase. This cycle repeats until the artifact is deemed to be acceptable to users. Although high fidelity prototypes can emerge from the process of rapid prototyping, rapid prototypes themselves are usually lo-fi. An example of rapid prototyping applied in an instructional design context is the successive approximation model or SAM (Allen, 2014). The SAM (version 2) process model is provided in Figure 2.

For example, a learning designer developing a course in a LMS can benefit from rapid prototyping processes like SAM2 before a course is deployed. After gathering information and materials (preparation phase), he or she can quickly incorporate as many course elements and materials as are immediately available into the LMS (iterative design phase). For any materials or content that is missing, simple placeholders are used with relevant descriptions (e.g., an image with an "X" on it to designate a graphic or a screenshot of a video player to designate a video). These materials are then arranged to provide a rough estimation of how the course navigation, structure, sequence, and associated learning materials will be organized. This is then reviewed by students (who do not necessarily need to be students enrolled in the course) and iterated over two or three redesign and revision cycles. Once the organization has been refined, course materials can be developed (e.g., multimedia, text-based content) and evaluated (iterative development phase). These materials are often evaluated by subject matter experts in the form of expert review. After two or three rounds of revisions and refinements are completed, the course is ready to be rolled out. Due to the revisions the course has a far greater likelihood to promote a positive learner experience than a course that is organized based solely on an LMS template or designer intuition.
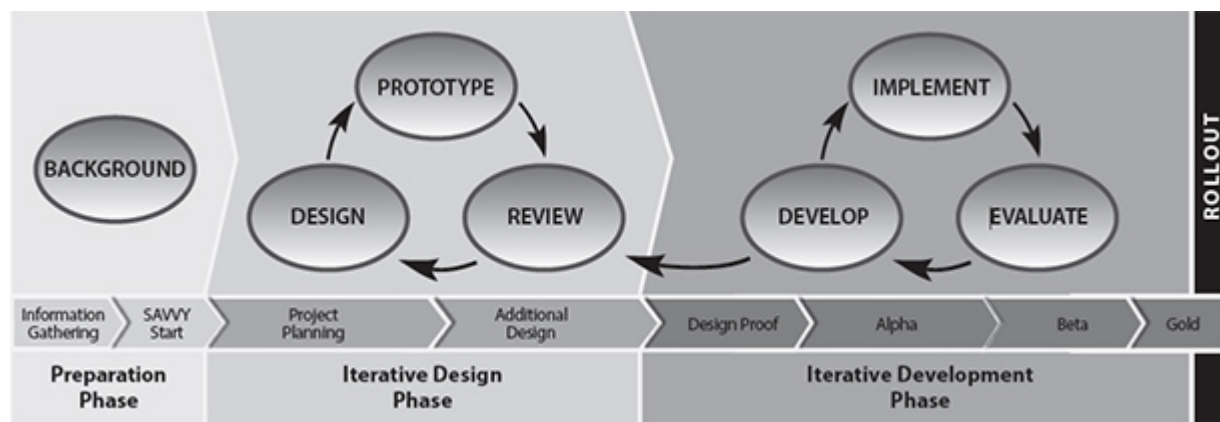
Figure 2

*Successive Approximation Model Version 2 (SAM2) Process Diagram*

Note. Adapted from Allen (2014). Copyright 2014 by the American Society for Training and Development.

3.2.2. Paper Prototyping

Paper prototyping is a lo-fi method of prototyping used to inform the design and development of many different kinds of interfaces, including web, mobile, and games. The focus of paper prototyping is not on layout or content but on navigation, workflow, terminology, and functionality. The purpose of creating these prototypes is to communicate designs among the design team, users, and stakeholders, as well as to gather user feedback on designs. A benefit of paper prototyping is that it is rapid and inexpensive—designers put only as much time into developing a design as is absolutely necessary. This makes it a robust tool at the early stages of design. As the name implies, designers use paper to create mockups of an interface. Using pencil and paper is the simplest approach to paper prototyping, but stencils, colored markers, and colored paper can also be used. These paper prototypes can be scanned and further elaborated using digital tools (Figure 3). The simplicity of paper prototyping allows for input from all members of a design team, as well as from users and other stakeholders. The speed of paper prototyping makes it particularly amenable to a rapid prototyping design approach. The process of creating paper prototypes can be individual, in which the designer puts together sketches on his or her own, or collaborative, in which a team provides input on a sketch while one facilitator draws it out. For further information on paper prototyping, refer to Snyder (2003) and UsabilityNet (2012).

For example, a learning designer planning to create a learning object using an authoring tool such as Articulate Storyline or Adobe Captivate can benefit from paper prototyping by establishing rough drafts of animations, interactions, or navigation before devoting time and effort to developing those things in the authoring environment. For example, Figure 3 illustrates a case vignette in which a child avatar with a behavior disorder gets into an intense verbal argument with a caregiver avatar. The scene sets up an interactive activity in which the learner selects from a variety of responses to the situation and receives specific feedback based on those decisions. The initial sketch considers visual design (sequence of scenes, positioning of the avatars, avatar facial expressions, placement of user interface elements, etc.), the tone of the language, potential animations (fade-in of "what could I do diff?"), how learners will interact with the learning object (e.g., should the scenes "autoplay" or should the user manually advance them?), and anticipates the following interactive activity. The design team has also added a design idea of potentially presenting the vignette in a comic book style. As the reader will note, there are deep and meaningful learning design considerations represented in this paper prototype that took less than three minutes to sketch, photograph, and digitally annotate. This then served as the basis for further discussions within the design team and to solicit feedback from a subject matter expert. These conclusions were then incorporated in another rapid prototype, and another, and so-on until the design was sufficiently developed to build out in a more robust authoring tool.
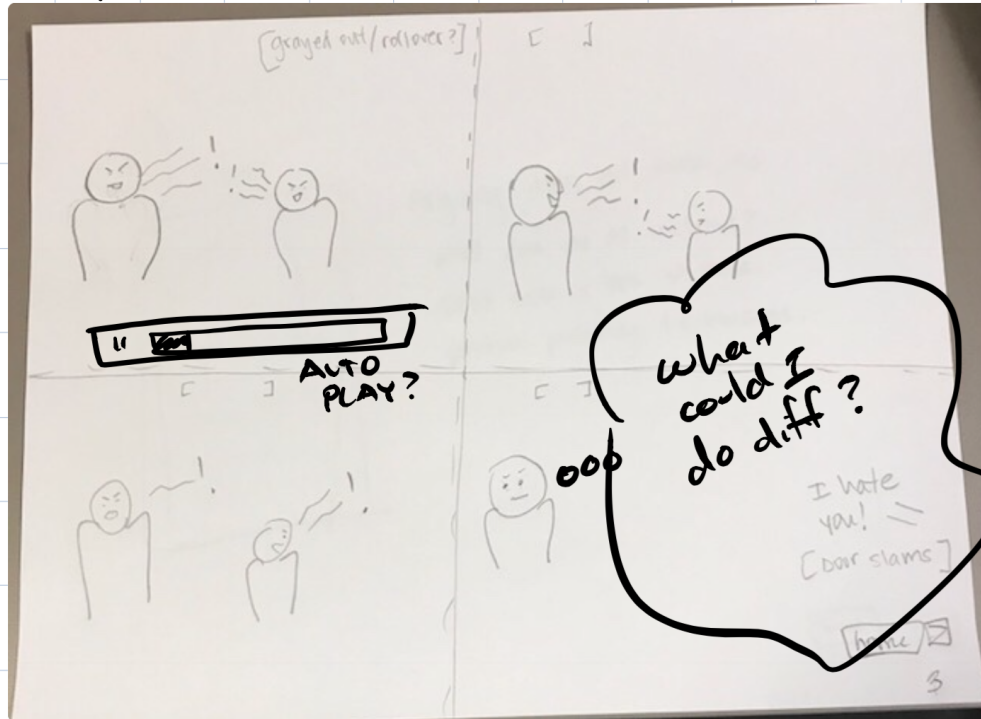
Figure 3

Example of a Paper Prototype That Has Been Scanned and Annotated Using Digital Tools

3.2.3. Wireframing

Wireframes are medium fidelity representations of interfaces that visually convey their structure (see Figure 4). Wireframing results in prototypes that are of higher fidelity than paper prototyping but lack the functionality and visual elements of high fidelity prototypes. Wireframing commonly occurs early in the design process after paper prototyping. It allows designers to focus on things that paper prototyping does not, such as layout of content, before more formal visual design and content creation occurs. Wireframing can be seen as an interim step that allows for fast mockups of an interface to be developed, tested, and refined, the results of which are then used to create higher fidelity, functional prototypes.
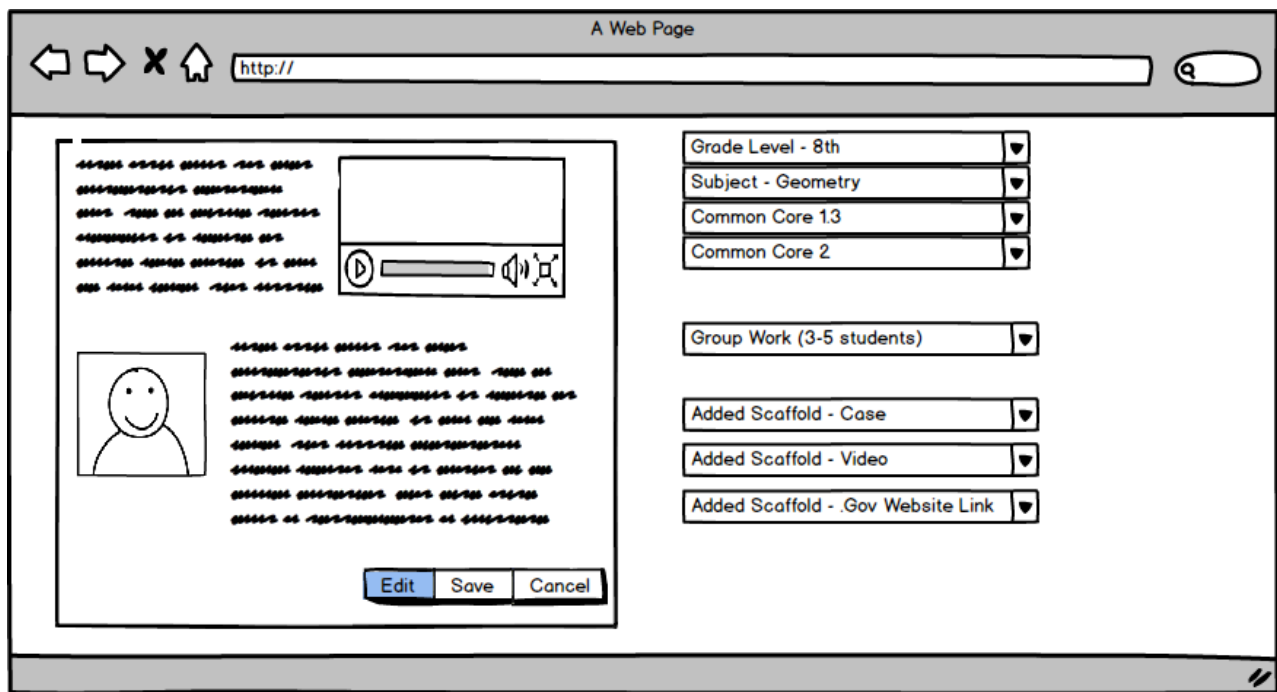
Figure 4

Example of a Wireframe

Wireframes consist of simple representations of an interface, with interface elements displayed as placeholders. Placeholders use a variety of visual conventions to convey their purpose. For example, a box with an "X" or other image might represent a graphic, or a box with horizontal lines might represent textual content. Wireframes can be created using common software such as PowerPoint or Google Drawings or with more specialized software such as OmniGraffle or Balsamiq. Wireframes are particularly amenable to revision, as revisions often consist of simple tweaks, such as moving interface elements, resizing, or removing them. A key benefit of wireframes is that they allow designers to present layouts to stakeholders, generate feedback, and quickly incorporate that feedback into revisions.

For example, learning designers developing a course in an LMS often incorporate multiple multimedia elements on a single LMS page. This could be a page consisting primarily of text interspersed with graphical illustrations or a page that presents three interactive three-dimensional models within a quiz. Learning designers can avoid unnecessary effort by developing wireframes for how content will be structured on these pages and then soliciting feedback. While creating wireframes for individual pages can increase designer efficiency, economies of scale can be achieved by wireframing entire learning modules and even entire course structures. These collections of wireframes provide a basis upon which to solicit feedback (i.e., from SMEs, students, etc.) and make subsequent improvements, thereby increasing the likelihood of a more positive learner experience. In addition, after designs are approved, the wireframe set can serve as a "punch list" for a learning design team, allowing the team to keep track of what content is needed, how it should be structured, and where it should be organized. As such, wireframes can be a tremendously useful communication and project management tool for a learning design team.

3.2.4. Functional Prototyping

Functional prototypes are higher-fidelity graphical representations of interfaces that have been visually designed such that they closely resemble the final version of the interface and that incorporate limited functionality. In some cases, content has been added to the prototype. A functional prototype might start out as a wireframe interface with links between screens. A visual design is conceived and added to the wireframe, after which graphical elements and content are added piece-by-piece. Then, simple functionality is added, typically by connecting different sections of the interface using hyperlinks. An advanced functional prototype might look like a real interface but lack full functionality. Functional prototypes can be created using PowerPoint or with more specialized software like InVision and UXPin. During

evaluation, functional prototypes allow for a learner to experience a mockup online course, mobile app, or educational software interface in a way that is very similar to the experience of using the actual product. However, because functionality is limited, development time can be reduced substantially. Functional prototypes provide a powerful way to generate feedback from learners in later stages of the learning design process, allowing for tweaks and refinements to be incorporated before time and effort are expended on development.

For example, imagine that a learning designer has received approval on a wireframe set for mobile microlearning materials for parents and caregivers of children with epilepsy (Figure 5). The designer imports the wireframes into InVision, a clickable prototyping tool, and sets up "hotspots" on the wireframe images. These hotspots are hyperlinks to other wireframes. By creating hotspots on all wireframes, the learning designer creates a simulation of how learners will interact with the mobile microlearning materials. The designer then sends this functional prototype to subject matter experts, who are attending an academic conference. These subject matter experts review the functional prototype and also share it with other academics in their discipline. By allowing other experts to actually experience how the mobile microlearning materials look and function, a wealth of informal feedback is generated that is then fed back to the learning designer. The learning designer then incorporates the expert feedback into the wireframes and creates a new clickable, functional prototype. This new functional prototype is then usability tested with a representative parent, and the process continues. In this way, content, visual design, and interaction design can all be tested before any actual learning materials are created or development takes place. This allows for continual, rapid, and targeted refinements, thereby increasing the likelihood for a positive learner experience.
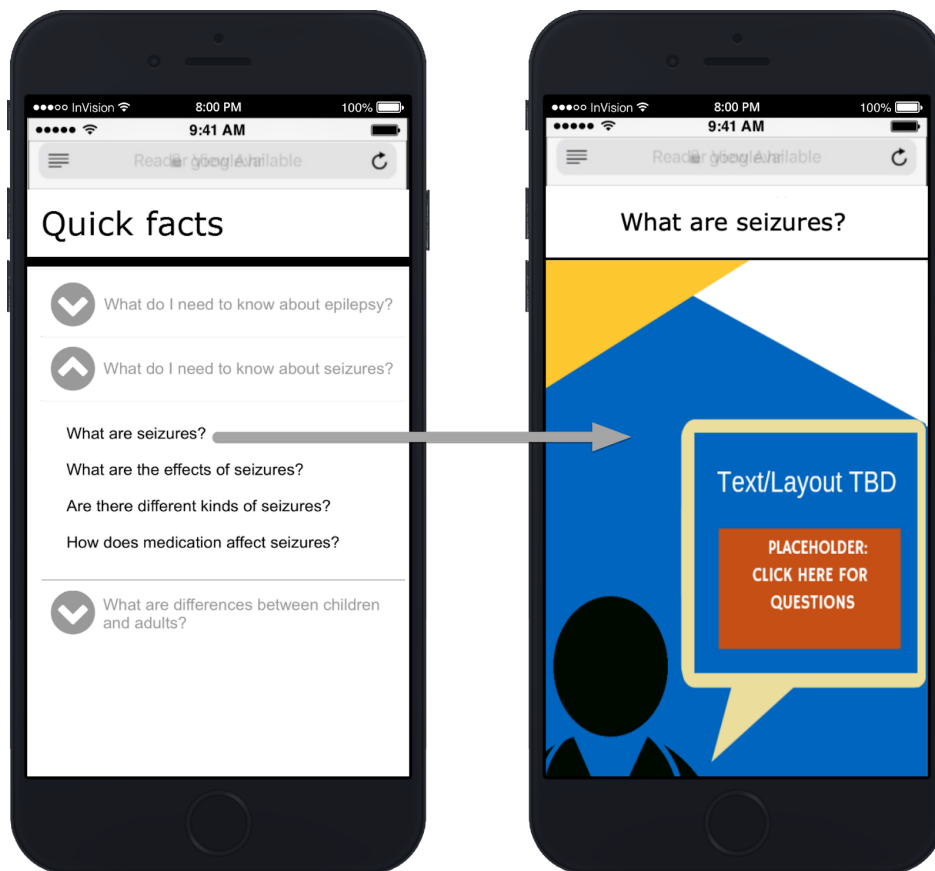
Figure 5

Functional Prototype of a Mobile Microlearning ASK System Developed for Parents of Children With Epilepsy Illustrating Clickable "Hotspots" That Allow Designers to Simulate How a Learning Environment Functions

To reiterate, the goal of UCD is to approach systems development from the perspective of the end-user. Using tools such as personas and prototypes, the learning design process becomes iterative, dynamic, and more responsive to

learner needs. Learning designers often use these tools in conjunction with a variety of evaluation methods to better align prototype interface designs with learners' mental models, thereby reducing cognitive load and improving usability. Evaluation methods are discussed in the following section.

4. Evaluation Methodologies for User-Centered Design

While UCD is important for creating usable interfaces, a challenge is knowing when and under what conditions to apply evaluation methodologies. In the following sections, several evaluation methodologies commonly used in UCD are described, with descriptions of how these evaluation methodologies can be used in a learning design context. These can be applied during various phases across the learning design and development process (i.e., front-end analysis, low-fidelity to high-fidelity prototyping). While a case can be made to apply any of the approaches outlined below in a given design phase, some evaluation methodologies are more appropriate to overall learner experience, while others focus more specifically on usability. Table 3 provides an overview of methods, in which design phase they can be best implemented, and associated data sources.

Table 3

Evaluation Methodologies, Design Phases, and Data Sources

Method	Front-end analysis	Prototyping			Data source
		Paper (low fidelity)	Wireframe (medium fidelity)	Functional (high fidelity)	
Ethnography	•				Single user or users
Focus groups	•	•			Group of users
Card sorting	•	•			Single user, multiple users or group of users
Cognitive walkthrough		•	•	•	Expert
Heuristic evaluation		•	•	•	Experts
A/B testing		•	•	•	Multiple users
Think-aloud				•	Multiple users
EEG/ Eyetracking				•	Multiple users
Analytics				•	Multiple users

4.1. Ethnography

A method that is used early in the front-end analysis phase, especially for requirements gathering, is ethnography. Ethnography is a qualitative research method in which a researcher studies people in their native setting (not in a lab or controlled setting). During data collection, the researcher observes the group, gathers artifacts, records notes, and performs interviews. In this phase, the researcher is focused on unobtrusive observations to fully understand the

phenomenon in situ. For example, in an ethnographic interview, the researcher might ask open-ended questions but would ensure that the questions were not leading. The researcher would note the difference between what the user is doing versus what the user is saying and take care not introduce his or her own bias. Although this method has its roots in the field of cultural anthropology, UCD-focused ethnography can support thinking about design from activity theory and distributed cognition perspectives (Nardi, 1996). This allows the researcher to gather information about the users, their work environment, their culture, and how they interact with the device or website in context (Nardi, 1997). This information is particularly valuable when writing user personas and scenarios. Ethnography is also useful if the researcher cannot conduct user testing on systems or larger equipment due to size or security restrictions.

A specific example of how ethnography can be applied in learning design is in the development of learner personas. Representative learners can be recruited for key informant interviews with the purpose of gathering specific data on what a learner says, thinks, does, and feels, as well as what difficulties or notable accomplishments they describe. The number of participants needed depends on the particular design context but does not need to be large. Indeed, learning designers can glean critical insights from just a few participants, and there is little question that even small numbers of participants is better than none. For example, to develop online learning resources for parents of children with traumatic brain injuries, a learning designer might interview two or three parents and ask them to relay what their typical day looks like, to tell a story about a particular challenge they have encountered with parenting their child, or to describe how they use online resources to find information about traumatic brain injury. The interviews could then be transcribed, and the learning designer could use a variety of analysis techniques to categorize the interview data thematically. For an approachable method of thematic analysis, the reader is referred to Mortinsen (2020). This information from thematic categories could then be generalized into the development of learner personas that are illustrative of themes derived from the key informant interviews.

4.2. Focus Groups

Focus groups are often used during the front-end analysis phase. Rather than the researcher going into the field to study a larger group as in ethnography, a small group of participants (5-10) are recruited based on shared characteristics. Focus group sessions are led by a skilled moderator who has a semi-structured set of questions or plan. For instance, a moderator might ask what challenges a user faces in a work context (i.e., actuals vs. optimals gap), suggestions for how to resolve it, and feedback on present technologies. The participants are then asked to discuss their thoughts on products or concepts. The moderator may also present a lo-fidelity prototype and ask for feedback. The role of the researcher in a focus group is to ensure that no single person dominates the conversation in order to hear everyone's opinions, preferences, and reactions. This helps to determine what users want and keeps the conversation on track. It is preferred to have multiple focus group sessions to ensure various perspectives are heard in case a conversation gets side-tracked. Analyzing data from a focus group can be as simple as providing a short summary with a few illustrative quotes for each session. The length of the sessions (typically 1-2 hours) may include some extraneous information, so it is best to keep the report simple.

For example, a learning designer developing an undergraduate introduction to nuclear engineering course invited a group of nuclear engineers, radiation protection technicians, and nuclear engineering students to participate in a focus group. The learning designer had created a semi-structured set of questions to guide the session. These questions focused on issues the designer had gleaned from discussions with subject matter experts and from document analysis, such as the upcoming challenge facing the industry of an aging workforce on the brink of retirement and with no immediate replacements, the stigma of nuclear power, and the perceived difficulty of pursuing a career in nuclear engineering. These issues were then explored with the focus group participants, with the designer acting as facilitator. Sticky notes were used to document key ideas and posted around the room. Participants were asked to use sticky notes to provide brief responses to facilitator questions. The facilitator then asked the participants to find the sticky notes posted on the walls that best aligned with the responses they had provided and post their sticky notes near those others. These groups of notes were then reviewed by the groups, refined, and then named. The entire process took two hours. These named groups ultimately formed the basis of the content units of the online course, such as using nuclear medicine to diagnose and treat cancer and irradiation of food to increase shelf life.

4.3. Card Sorting

Aligning designs with users' mental models is important for effective UX design. A method used to achieve this is card sorting. Card sorting is used during front-end analysis and paper prototyping. Card sorting is commonly used in psychology to identify how people organize and categorize information (Hudson, 2012). In the early 1980s, card sorting was applied to organizing menuing systems (Tullis, 1985) and information spaces (Nielsen & Sano, 1995).

Card sorting can be conducted physically using tools like index cards and sticky notes or electronically using tools like Miro (https://miro.com/) or Lloyd Rieber's Q Sort (http://lrieber.coe.uga.edu/qsort/index.html). It can involve a single participant or a group of participants. With a single participant, he or she groups content (individual index cards) into categories, allowing the researcher to evaluate the information architecture or navigation structure of a website. For example, a participant might organize "Phone Number" and "Address" cards together. A set of cards placed together by multiple participants suggests to the designer distinct pages that can be created (e.g., "Contact Us"). When focusing on a group, the same method is employed, but the group negotiates how they will group content into categories. How participants arrange cards provides insight into mental models and how they group content.

In an open card sort, a participant will first group content (menu labels on separate notecards) into piles and then name the category. Participants can also place the notecards in an "I don't know" pile if the menu label is not clear or may not belong to a designated pile of cards. In a closed card sort, the categories will be pre-defined by the researcher. It is recommended to start with an open card sort and then follow-up with a closed card sort (Wood & Wood, 2008). As the arrangement of participants are compared, the designer iterates the early prototypes so the menu information and other features align with how the participants organize the information within their mind. For card sorting best practices, refer to the work of Righi et al (2013).

Card sorting is particularly useful for learning designers creating courses in learning management systems. After identifying the various units, content categories, content sections, etc., the learning designer can (a) write these down on cards (or use other methods discussed above); (b) present them to a SME, course instructor, or student; and (c) ask them to arrange the cards into what they perceive to be the most logical sequence or organization. This approach can be particularly educative when comparing how instructors feel a course should be organized with how a learner feels a course should be organized, which can sometimes be quite disparate. Findings can then be used to inform the organization of the online course.

4.4. Cognitive Walkthroughs

Cognitive walkthroughs (CW) can be used during all prototyping phases. CW is a hands-on inspection method in which an evaluator (not a user) evaluates the interface by walking through a series of realistic tasks (Lewis & Wharton, 1997). CW is not a user test based on data from users, but instead is based on the evaluator's judgments.

During a CW, a UX expert evaluates specific tasks and considers the user's mental processes while completing those tasks. For example, an evaluator might be given the following task: Recently you have been experiencing a technical problem with software on your laptop and you have been unable to find a solution to your problem online. Locate the place where you would go to send a request for assistance to the Customer Service Center. The evaluator identifies the correct paths to complete the task but does not make a prediction as to what a user will actually do. In order to assist designers, the evaluator also provides reasons for making errors (Wharton et al., 1994). The feedback received during the course of the CW provides insight into various aspects of the user experience including:

- first impressions of the interface,
- how easy it is for the user to determine the correct course of action,
- whether the organization of the tools or functions matches the ways that users think of their work,
- how well the application flow matches user expectations,
- whether the terminology used in the application is familiar to users, and
- whether all data needed for a task is present on screen.

In learning design, the CW is particularly valuable when working in teams that consist of senior and junior learning designers. Junior learning designers can develop prototype learning designs (e.g., learning modules, screencasts, infographics), which can then be presented to the senior designer to perform a cognitive walkthrough. For example, a junior designer creates a series of five videos and sequences them in the LMS logically so as to provide sufficient information for a learner to correctly answer a set of corresponding informal assessment questions (e.g., a knowledge check). The junior designer then presents this to the senior designer with the following scenario: You don't know the answer to the third question in the knowledge check, so you decide to review what you learned to find the answer. The senior designer then maps out the most efficient path to complete this task but finds that videos cannot be easily scrubbed by moving the playhead rapidly across the timeline. Instead, the playhead resets to the beginning of the video when it is moved. The senior designer explains to the junior designer that learners would have to completely rewatch each video to find the correct answer, and the junior designer then has specific feedback that can be used to improve the learner experience for this learning module.

4.5. Heuristic Evaluation

Heuristic evaluation is an inspection method that does not involve directly working with the user. In a heuristic evaluation, usability experts work independently to review the design of an interface against a predetermined set of usability principles (heuristics) before communicating their findings. Ideally, each usability expert will work through the interface at least twice: once for an overview of the interface and the second time to focus on specific interface elements (Nielsen, 1994). The experts then meet and reconcile their findings. This method can be used during any phase of the prototyping cycle.

Many heuristic lists exist that are commonly used in heuristic testing. The most well-known heuristic checklist was developed over 25 years ago by Jakob Nielsen and Rolf Molich (1990). This list was later simplified and reduced to 10 heuristics which were derived from 249 identified usability problems (Nielsen, 1994). In the field of instructional design, others have embraced and extended Nielsen's 10 heuristics to make them more applicable to the evaluation of eLearning systems (Mehlenbacher et al., 2005; Reeves et al., 2002). Not all heuristics are applicable in all evaluation scenarios, so UX designers tend to pull from existing lists to create customized heuristic lists that are most applicable and appropriate to their local context. Nielsen's 10 heuristics are:

1. Visibility of system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation

An approach that bears similarities with a heuristic review is the expert review. This approach is similar in that an expert usability evaluator reviews a prototype but differs in that the expert does not use a set of heuristics. The review is less formal and the expert typically refers to personas to become informed about the users. Regardless of whether heuristic or expert review is selected as an evaluation method, data from a single expert evaluator is insufficient for making design inferences. Multiple experts should be involved, and data from all experts should be aggregated. This is because expert review is particularly vulnerable to an expert's implicit biases. Different experts will have different perspectives and biases and therefore will uncover different issues. Involving multiple experts helps ensure that implicit bias is reduced and that problems are not overlooked.

For learning designers developing online courses, established quality metrics such as Quality Matters (QM) can be used for guiding heuristic evaluations (MarylandOnline, Inc, 2018). QM provides evaluation rubrics for certified evaluators to

assess the degree to which an online course meets QM standards. The aggregate QM score can then be used as a quality benchmark for that course. However, when applied in the context of a heuristic evaluation, the QM materials should only be used to evaluate prototypes in the interest of making improvements and not for establishing a quality benchmark for a finalized course. A QM-guided heuristic evaluation performed by a skilled evaluator can provide tremendously valuable insights along the dimensions of learner experience outlined above. These can serve as the basis for subsequent design refinements to an online course, which promotes a more positive overall learner experience.

4.6. A/B Testing

A/B testing or split-testing compares two versions of a user interface and, because of this, all three prototyping phases can employ this method. The different interface versions might vary individual screen elements (such as the color or size of a button), typeface used, placement of a text box, or overall general layout. During A/B testing, it is important that the two versions are tested at the same time by the same user. For instance, Version A can be a control and Version B should only have one variable that is different (e.g., navigation structure). A randomized assignment, in which some participants receive Version A first and then Version B (versus receiving Version B and then Version A), should be used.

Learning designers do not frequently have access to large numbers of learners for A/B testing, and therefore need to consider how to adapt this approach to specific design contexts. For example, a design team building a case library for a case-based learning environment is struggling with the design of the cases themselves. One learning designer has created a set of cases that highlight the central theme of the different cases but are fairly text heavy. Another learning designer has taken a different design approach and created a comic-book layout for the cases, which has visual appeal, but the central theme of the cases is not emphasized. The design team asks six students to review the designs. Three students review the more thematically-focused cases and three review the comic-book cases. The students are then asked to create a concept map that shows the central themes of the cases and how those themes are connected. The design team learns that students who used the thematically-focused cases spent much less time reviewing the cases and their concept maps show a very shallow understanding of the topic, although they did appropriately identify thematic areas. The students who used the comic-book cases spent more time reviewing the cases, and their concept maps are richer and show a more nuanced understanding of the topic, despite missing the specific names of the thematic areas (although they describe the areas in their own words). With this information, the team decides to continue iterating prototypes of the comic-book design while better emphasizing the central themes within those cases. On this basis, a potentially more effective learner experience was uncovered.

4.7. Think-Aloud User Study

Unlike A/B testing, a think-aloud user study is only used during the functional prototyping phase. According to Jakob Nielsen (1993), "thinking aloud may be the single most valuable usability engineering method" (p. 195). In a think-aloud user study, a single participant is tested at any given time. The participant narrates what he or she is doing, feeling, and thinking while looking at a prototype (or fully functional system) or completing a task. This method can seem unnatural for participants, so it is important for the researcher to encourage the participant to continue verbalizing throughout a study session. To view an example of a think-aloud user study, please watch [Steve Krug's "Rocket Surgery Made Easy" video](#).

A great deal of valuable data can come from a think-aloud user study (Krug, 2010). Sometimes participants will mention things they liked or disliked about a user interface. This is important to capture because it may not be discovered in other methods. However, the researcher needs to also be cautious about changing an interface based on a single comment.

Users do not necessarily have to think-aloud while they are using the system. The retrospective think-aloud is an alternative approach that allows a participant to review the recorded testing session and talk to the researcher about what he or she was thinking during the process. This approach can provide additional helpful information, although it

may be difficult for some participants to remember what they were thinking after some time. Hence, it is important to conduct retrospective think-aloud user testing as soon after a recorded testing session as possible.

Think-aloud user testing is the most widely used method of usability evaluation in practice, including in the field of LIDT. Indeed, usability testing has long been recognized as a useful evaluation method in the design of interactive learning systems (cf. Reeves & Hedberg, 2003). Increasingly, usability testing is gaining acceptance in LIDT as a viable and valuable evaluation method for informing research related to advanced or novel learning technologies, for which existing research is neither substantial nor sufficient, such as 360-video based virtual reality (Schmidt et al., 2019) or digital badging (Stefaniak & Carey, 2019). Given the limited resources provided to learning designers, think-aloud user testing is particularly attractive because it can be conducted with relatively small numbers of participants (often only five participants are needed to assess the usability of an online course) and with open source or free-to-use tools. For a primer on how to conduct think-aloud user testing, readers are referred to the U.S. government's online resources for usability at https://www.usability.gov.

4.8. Eye-Tracking

Similar to the think-aloud user study, eye-tracking is an evaluation method that involves the user during the functional prototype phase. Eye-tracking is a psychophysiological method used to measure a participant's physical gaze behavior in responses to stimuli. Instead of relying on self-reported information from a user, these types of methods look at direct, objective measurements in the form of gaze behavior. Eye-tracking measures saccades, eye movements from one point to another, and fixations, areas where the participant stops to gaze at something. Saccades and fixations can be used to create heat maps and gaze plots, as shown in Figures 6-8, or for more sophisticated statistical analysis.
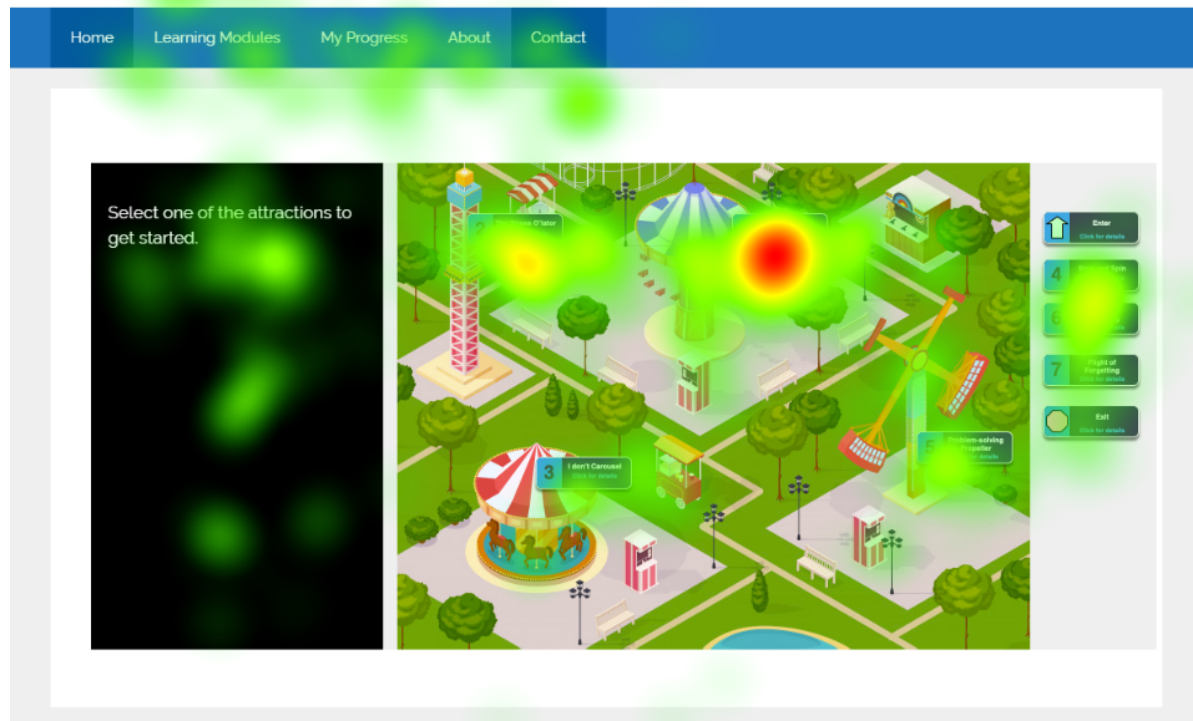
Figure 6

Heat Map of a Functional Prototype's Interface Designed to Help Learners With Type 1 Diabetes Learn to Better Manage Their Insulin Adherence

Note. Eye fixations are shown with red indicating longer dwell time and green indicating shorter dwell time. Photo courtesy of the Advanced Learning Technologies Studio at the University of Florida. Used with permission.
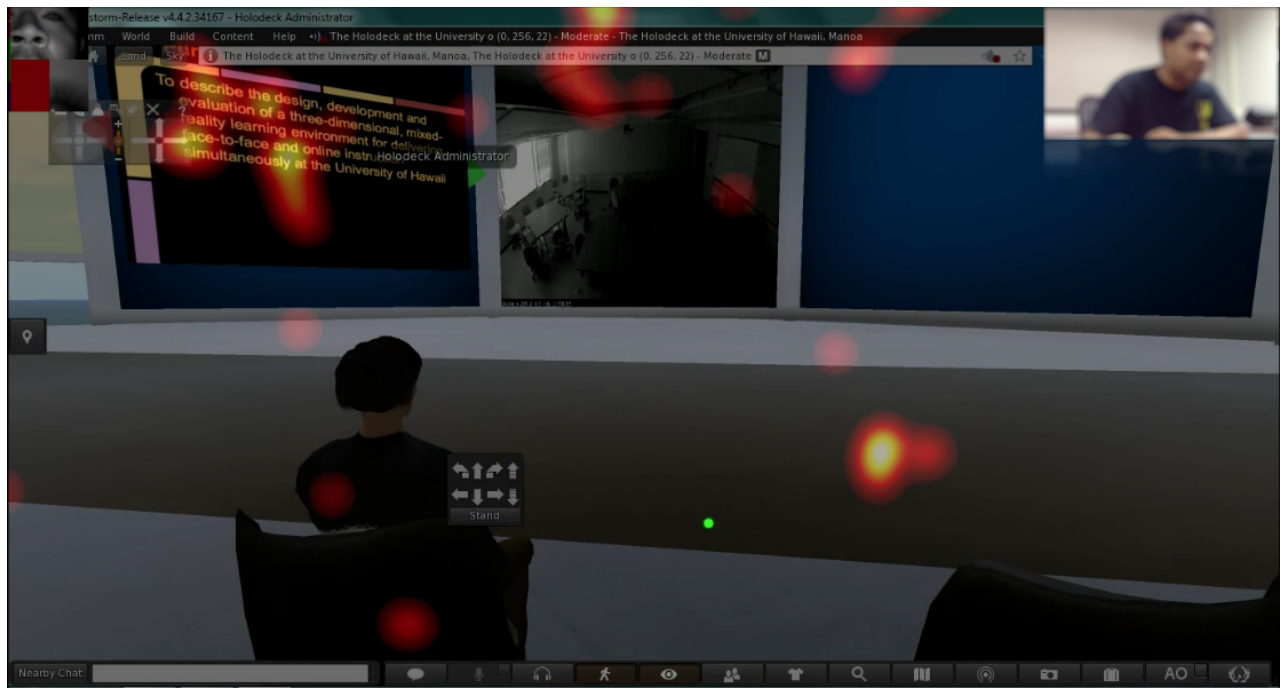
Figure 7

Heat Map of a Three-Dimensional Interface Showing Eye Fixations and Saccades in Real-Time, With Yellow Indicating Longer Dwell Time and Red Indicating Shorter Dwell Time

Note. Adapted from Schmidt et al. (2013). Reprinted with permission.
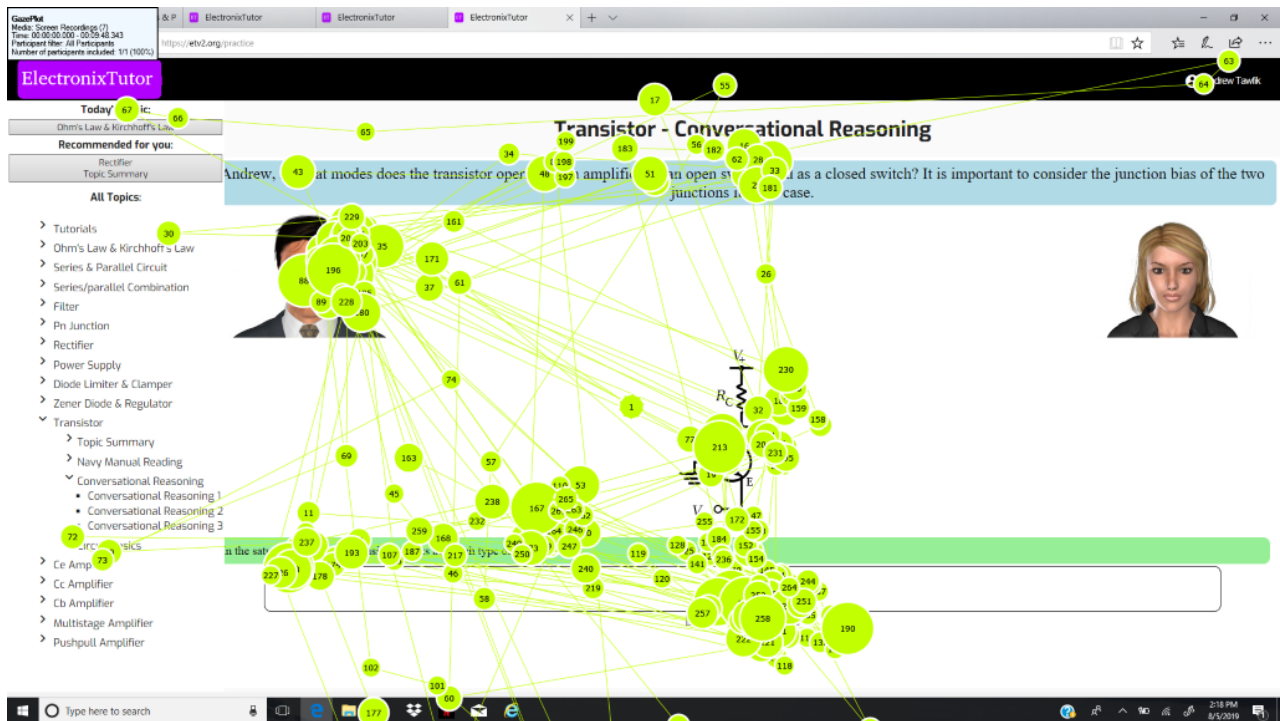
Figure 8

Gaze Plot of a Learner Engaged With the ElectronixTutor Learning Environment

Note. Photo courtesy of the Instructional Design Studio at the University of Memphis. Used with permission.

4.9. Electroencephalogy

Another psychophysiological method used to directly observe participant behavior is electroencephalogy (EEG). EEG measures participant responses to stimuli in the form of electrical activity in the brain. An EEG records changes in the brain's electrical signals in real-time. A participant wears a skull cap (Figure 9) with tiny electrodes attached to it. While viewing a prototype, EEG data such as illustrated in Figure 10 can show when a participant is frustrated or confused with the user interface (Bergstrom et al., 2014).

From the perspective of learning design, eye-tracking and EEG-based user testing are typically reserved for very large training programs (i.e., for large corporations like Apple or Facebook) or for learning designs that are more focused on research than on practical application. It is not very common for small learning design teams to have access to EEG and eye tracking resources. Nonetheless, these approaches can serve as a way to understand when learners find something important, distracting, disturbing, etc., thereby informing learning designers of factors that can impact extraneous cognitive load, arousal, stress, and other factors relevant to learning and cognition. A disadvantage of this type of data, for example, is that it might not be clear why a learner was fixated on a search field, why a learner showed evidence of stress when viewing a flower, or if a fixation on a 3D model of an isotope suggests learner interest or confusion. In these situations, a retrospective think-aloud can be beneficial. After the eye-tracking data have been collected, the learning designer can sit down with a participant and review the eye-tracking data while asking about eye movements and particular focus areas.

Figure 9

A Research Study Participant Wears an EEG While Viewing an Interface

Note. Photo courtesy of the Neuroscience Applications for Learning (NeurAL Lab) at the University of Florida. Used with permission.
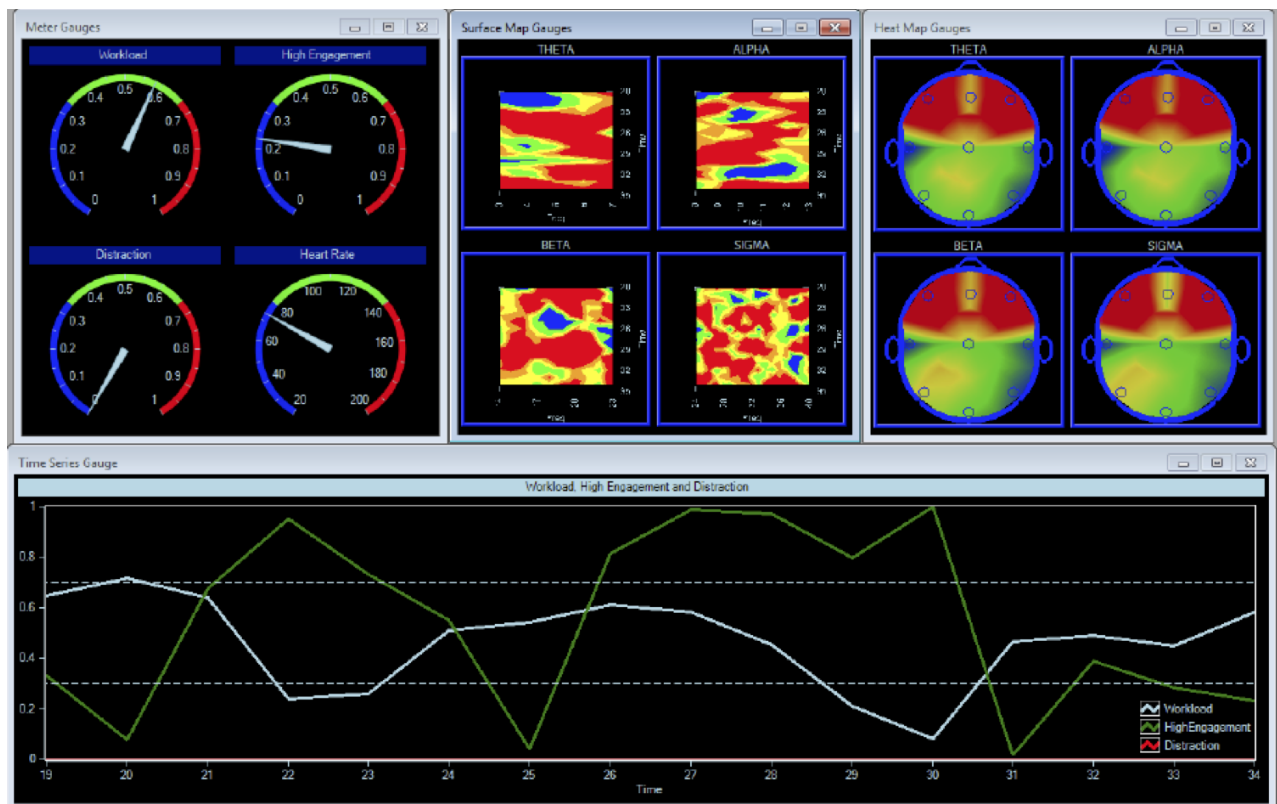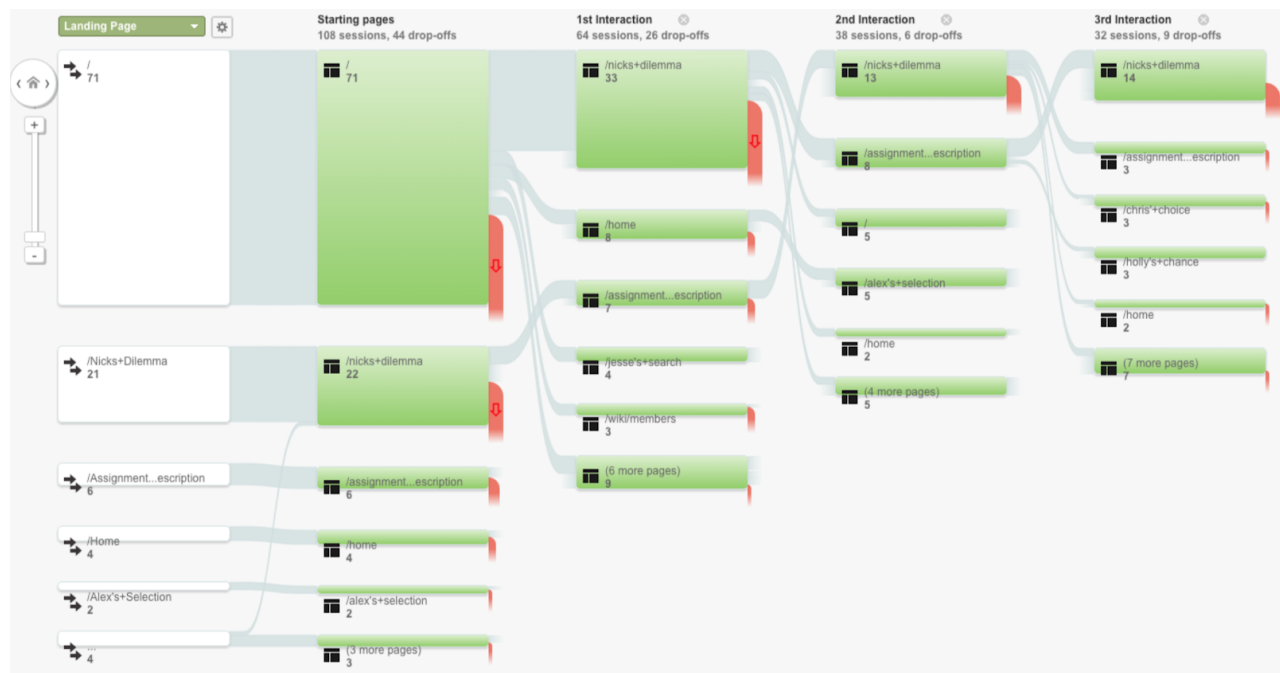
Figure 10

Output From EEG Device in a Data Dashboard Displaying a Variety of Psychophysiological Measures (e.g., Workload, Engagement, Distraction, Heart Rate)

Note. Photo courtesy of the Neuroscience Applications for Learning (NeurAL Lab) at the University of Florida. Used with permission.

4.10. Analytics

A type of evaluation method that is gaining significant traction in the field of learning design due to advances in machine learning and data science is analytics. Analytics are typically collected automatically in the background while a user is interfacing with a system and sometimes without the user even being aware the data are being collected. An example of analytics data is a clickstream analysis in which the participants' clicks are captured while browsing the web or using a software application (see Figure 11). This information can be beneficial because it can show the researcher the path the participant was taking while navigating a system. Typically, these data need to be triangulated with other data sources to paint a broader picture.

Figure 11

An Example of a Clickstream, Showing Users' Paths Through a System

Note. Adapted from Schmidt & Tawfik (2019). Reprinted with permission.

Increasingly, learning analytics and data dashboards are being incorporated into the tools of the learning design trade, including LMSs, video conferencing suites, video hosting providers, and a myriad of others. Indeed, the massive collection of learners' personal usage data has become so ubiquitous that it is taken for granted. However, analytics and data dashboards remain novel tools that learning designers do not necessarily have the training to use for making data-based decisions for improving learning designs. That said, data dashboards are maturing quickly. Less than a decade ago, only the most elite learning designers could incorporate learning analytics and data dashboards into their designs, whereas today these tools are built-in to most tools. Clearly, these tools have enormous potential for the field of LIDT, for example, for creating personalized learning environments, providing individualized feedback, improving motivation, and so-on. With advances in machine learning and artificial intelligence, learning analytics hold great promise; however, privacy concerns, questions of who owns and controls learner data, and other issues remain. Learning designers are encouraged to carefully review the data usage agreements of the software used for developing and deploying digital environments for learning. As mentioned previously in this chapter, LX considers the entire experience of the learner when using a technology, which includes their experiences with the collection of personal data. Carefully safeguarding this data and using it judiciously is paramount for a positive learner experience.

5. Conclusion

As digital tools for learning have gained in popularity, there is a rich body of literature that has focused on designing for learning with and through these tools. Indeed, a variety of principles and theories (e.g., cognitive load theory, distributed cognition, activity theory) provide valuable insight to situate the learning design process. While the design of learning technologies is not new, issues of how learners interact with the technology can sometimes become secondary to pedagogical concerns.

In this chapter, we have illustrated how the field of HCI intersects with the field of instructional design and provided specific examples of how to approach learning design using methods and processes commonly associated with UCD. Moreover, we have provided examples of iterative design processes and commonly used evaluation methodologies that

can be employed to advance usable and pleasing learning designs, along with illustrative examples of how these methods and processes can be used in practice. The concepts of HCI, UX, and UCD provide insight into how learning technologies are used by educators and learners. A design approach that connects the principles of UCD with theories and processes of learning design can help ensure that digital environments for learning are constructed in ways that best support learners' achievement of their learning goals.

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Paradigms of Knowledge Production in Human-Computer Interaction: Towards a Framing for Learner Experience (LX) Design

Colin M. Gray

Design   User Experience   Human-computer Interaction   Epistemology   Paradigms

In this chapter, I contextualize the knowledge production of the human-computer interaction (HCI) community within broader epistemological, historical, and disciplinary framings of this scholarship. I describe the historical landscape of HCI as a discipline, including the significant subcommunities that have formed over time as the discipline has become more inclusive of disciplines and forms of knowledge. This description will map across cognitivist, social constructivist, and humanist/design threads of the community, all of which are still active participants in the creation of HCI knowledge. These threads are contextualized for a learning, design, and technology (LDT) audience, including historical and theoretical connections to scientific and humanist modes of instructional design scholarship. I conclude with a preliminary grounding for learner experience (LX) design and a conceptual roadmap that draws from strengths in the LDT and HCI communities.

1. Introduction

User-centered approaches to design have experienced rapid adoption in industry contexts in the last decade, with the underlying promise of a better connection to user needs and experiences, and ultimately, increased profit (Brown, 2009; R. L. Martin, 2009). This approach, often known by the moniker "design thinking," has been taken on perhaps most substantially by practitioners known as user experience (UX) designers—a transdisciplinary role that builds upon and beyond elements from psychology, graphic design, and anthropology, among other disciplines. UX design has risen in prominence in conjunction with "design-first" approaches. However, the roots of UX—including a focus on user experience, user needs, and attendance to the socio-cultural and organizational contexts of use—have their origin in numerous disciplinary traditions, including human-computer interaction (HCI), interaction design (IxD), cognitive psychology, and human factors. Even now, the definition, core knowledge, and disciplinary perspective of UX designers is contested and rapidly growing (Kou & Gray, 2018; Lallemand et al., 2015).

While UX design is the most dominant job title umbrella relating to human-centered design, its lack of precise origin means that there is little cohesive intellectual history that might be accessible to an instructional design audience. To account for this, I will focus on the HCI domain due to its importance and longevity in the study of interactions of people with technology, and due to its present role in theoretically informing many UX practices. I will frame this discussion specifically on knowledge production in HCI and the ontological and epistemological dimensions of that production that

rest on disciplinary perspectives, concepts, and historical patterns of inquiry that use this perspective as a means of identifying connections and tensions with LDT scholarship and practice. By LDT, I refer both to communities of scholarship and practice that have relevance to learning theory, instructional theory, and the uptake of this knowledge in the creation of learner experiences in many educational forms and contexts, including informal learning, K-12 education, higher education, workforce development, and corporate training. Formal manifestations of LDT might include graduate programs in instructional design, instructional technology, educational technology, or the learning sciences.

In this chapter, I will set the stage for the emergence of a transdisciplinary learner experience (LX) designer role, attempting to align—or at the very least, raise—disciplinary perspectives from HCI, UX, and LDT. First, I will provide an overview of my positionality as a researcher and scholar in these communities, which may be useful in identifying points of overlap and also potentially lack of awareness to certain literature. Second, I will outline historical and current patterns of knowledge production and disciplinary engagement in HCI. Third, I will situate theories, concepts, and methods from HCI and UX perspectives that may have value from an LDT perspective. Fourth, I will offer a preliminary conceptual roadmap and grounding for the future LX design discipline. Through these sections, I intend to outline a means through which HCI scholarship might be contextualized and interpreted by instructional designers, connecting disparate conceptual and methodological vocabulary, while also providing a means of describing different epistemological orientations that impact the uptake of this knowledge.

2. Researcher Positionality

As part of any critical praxis, it is important to recognize the experiences and disciplinary perspectives to which we relate, which vocabularies we rely upon, and where in turn these experiences and perspectives might introduce areas of weakness and strength in knowledge building. I currently do scholarship at the intersections of LDT, human-computer interaction (HCI), and design, with particular areas of focus in design education, ethics and social responsibility, translational science, and design practice. I earned a BS and MA in graphic design, with a strong focus on web development and new media, with overlapping interests in art history, art criticism, and semiotics. I was first introduced to the field of instructional design as an art director for a management consultancy, where I served as an art director, and later took on substantial responsibilities for learning strategy and technological implementation. Parallel to this work experience, I earned a MEd in educational technology, where I became familiar with learning theory and theories of instructional design. By the time I began my PhD in instructional systems technology in 2010, I had substantial familiarity with the nature of "real world" instructional design practice, but this experience did not resonate with my understanding of theories and knowledge building practices in the field. Through my work with my doctoral advisor, Elizabeth Boling, I began to explore the broader world of design theory and the role of design in LDT (Boling & Smith, 2018). In parallel, I discovered the world of HCI, which at Indiana University was—and still is—strongly linked to transdisciplinary design theory and practice. During my doctoral work, I had the opportunity to conduct studies and publish work in multiple areas of disciplinary focus, including HCI, design, and education, and it was through this set of experiences that I began to identify opportunities for translational work between academia and practice, and in a transdisciplinary sense across, through, and above established disciplines.

I share this background to temper expectations regarding what perspectives I can account for, as well as to show the deeply subjective and experiential role that all of us occupy as researchers, instructors, and designers. To use Schön's (1990) language of repertoire, the vocabularies, theories, methods, concepts, and processes of each of these fields have left a unique imprint on my way of seeing the world and impacts my praxis in ways that are not even fully accessible to me (Boling et al., 2017). Thus, I will present one view of how HCI and LDT might productively be connected. You, the reader, will have to confront differing epistemological traditions, the difference in disciplinary patterns of knowledge production, and even the difference in philosophical and critical orientations and choose your own path forward. I will seek to leave behind the "breadcrumbs" of my own experience so you can find your own path through the literatures of these fields, with the goal of defining your own transdisciplinary practice.

3. HCI as a Discipline

In the 1960s and 1970s, the need to engage everyday users in the operation of technological systems birthed the field of human-computer interaction (HCI), concretized through shared interest among cognitive psychologists, computer scientists, and human factors engineers. HCI has existed since this time under many different academic framings, including computer science, information science, human factors, and informatics. While the field has built extensive scholarly knowledge through conferences (most notably the ACM CHI Conference on Human Factors in Computing Systems, or "CHI"), the lack of undergraduate programs in the field have led to a lack of general awareness of this community, particularly within the educational community. Exacerbating this issue of awareness, HCI—like its computer science siblings—has historically prioritized conference publications, which are refereed at an equivalent level to journal articles in education and other fields. Thus, CHI conference publications and those of partner conferences (e.g., DIS, CSCW, Creativity and Cognition, UIST) are considered to contain the most rigorous knowledge in the HCI field. While the HCI community is not as large as the educational research community, writ large, the field is highly productive, with 647 full papers (roughly equivalent in prestige and rigor to journal papers in education) accepted at the 2020 CHI conference alone.

Given the modern awareness of UX Design, particularly in the rise of design approaches in industry, it is also important to situate UX within or in relation to HCI. First, while many UX designers are trained in graduate HCI or Information Science programs, these paths are not exclusive or predetermined; many UX designers originate in other fields, such as industrial design, graphic design, computer science, or marketing. Thus, many fields consider themselves to have some claim to UX, which is aligned with program offerings and common degree paths—made possible because UX in some ways is more of a philosophy than a concrete and objectively defined set of skills or theoretical perspectives. Second, while UX approaches and methods resonate strongly with trends of human-centered design within HCI, UX is not generally considered to be a subset of HCI, but rather a superset. This means that while HCI knowledge can often be seen as foundational to UX practice, many practitioners do their work quite ably without this full historical backdrop (Gray et al., 2014). Third, a gap in research and practice has resulted in a lack of resonance and awareness between the knowledge produced in academic settings, and the knowledge required to expertly inform expert practice. This gap, like those in many other fields, points towards mismatches in knowledge generation, categorization, and eventual use (Colusso et al., 2019; Gray et al., 2014). For all of these reasons, I cannot present HCI knowledge production as a totalizing force over all of UX practice; instead, I position HCI as one of multiple traditions that might inform a future LX role, and one that I am perhaps uniquely positioned to share and contextualize to an LDT audience due to my educational background and research foci.

HCI has a long and tumultuous history, marked by the rapid rise of technological capability, the equally rapid uptake of technology in society, and the diversification of knowledge from scholars who have introduced theoretical and conceptual lenses from a range of disciplinary perspectives. These expansions of the field over time have been theorized by multiple scholars using the language of "waves" and/or "paradigms" (Table 1). While each of these mapping approaches is reductionist in at least one dimension, these accounts of HCI scholarship may help to establish the types of perspectives that the field has historically valued, and the epistemological orientation of the knowledge generated through a given perspective. In consolidating these differing perspectives, one might be tempted to see certain perspectives as more "evolved" than others, or to think that—like Kuhnian shifts—certain perspectives are no longer in vogue. In contemporary HCI scholarship, knowledge is still produced in all three paradigms, waves, and sets of typical theoretical approaches. At the annual CHI conference, papers stemming from all three of these traditions are present, and valued for their respective merits by subsets of the overall community. However, the boundaries and field of view of each perspective are still epistemologically and ontologically limited. As Harrison et al. (2007) articulate: "The 1st and 2nd paradigms emphasize the importance of objective knowledge. The 3rd paradigm, in contrast, sees knowledge as arising from situated viewpoints in the world and often sees the dominant focus on objective knowledge as suspect in riding roughshod over the complexities of multiple perspectives at the scene of action" (p. 13). Thus, we can see the continued value of engineering-focused perspectives suggested by the 1st wave, while also identifying new opportunities when engaging in humanistic approaches in a 3rd wave stance (Bardzell & Bardzell, 2015).

Table 1

Historical and Conceptual Alignment of Paradigms, Waves, and Typical Theoretical Approaches in HCI

	One	Two	Three
Paradigms (adapted from Harrison et al., 2011, 2007)	Interaction as "man-machine coupling," with a focus on optimizing fit between person and machine.	Interaction as information communication, with a focus on optimizing accuracy and efficiency of information transfer.	Interaction as phenomenologically situated, with a focus on support for situated action in the world.
Waves (adapted from Bannon, 1995; Bødker, 2006)	Individuals "rationally" operate technological systems to accomplish work tasks.	Groups work together with a collection of applications, primarily in work settings and through interaction in well-established communities of practice	Interaction moves from the workplace to our homes and everyday lives and culture. This interaction is increasingly non-work, non-purposeful, and non-rational.
Typical theoretical approaches (adapted from Rogers, 2012)	• Cognitive modeling • Human factors	• External cognition • Distributed cognition • Ecological psychology • Ethnography and ethnomethodology • Situated action • Activity theory	• Embodiment • Experience • Design • Cultural studies • Critical theory, queer theory, feminist theory, post-colonial theory, post-humanism

The interaction(s) among these perspectives is, in many ways, the greatest potential strength of HCI as a field. New paradigms may illuminate hidden concerns in other paradigms; some paradigms might reframe issues such that approaches taken within other paradigms are seen to be inappropriate or ill-structured. And ultimately, the reframing of HCI outcomes as being designed has shifted priorities from experimentally verifiable and objective knowledge (e.g., 2nd wave or paradigm) to socially and culturally defined subjective knowledge (e.g., 3rd wave or paradigm). For instance, while design knowledge in the second wave is primarily concerned with guidelines or prescriptions that are repeatable regardless of context or user, design knowledge in the third wave encapsulates multiple types of knowledge (cf. intermediate-level knowledge; Löwgren, 2013) that are under the control of the designer and the decisions that she chooses to make. Thus, Harrison et al. (2007) position this change in perspective as a shift from "verified design and evaluation methods" to "a palette of situated design and evaluation strategies." This view of design activity and the heightened role of the designer is resonant with recent work in the LDT community describing the subjective-yet-professional role of the designer in creating the not-yet-existing (e.g., Boling et al., 2017; Gray et al., 2015).

An example might be helpful in drawing distinctions—and potential connections—across these three waves or paradigms. Consider the design of a tool to encourage communication among individuals. In the first wave or paradigm, this would automatically be assumed to take place within a work setting, since this performance dimension was initially the center of the field. Rather than considering communication as emergent or situated, the focus would be on optimizing fit between person and machine, with the metaphor of human as a machinist "cog" as the primary metaphorical framing. In this context, it is difficult to engage with any philosophical position other than that of efficiency or speed of production. If the human is a cog—and often as a solitary actor working in tandem with a larger machine—then the goal should be to optimize fit and remove any barriers to increased efficiency, and thus any focus of

encouraging communication would have to focus on the working of humans as rational actors (Card et al., 1983). This might feel most similar in approach to programmed instruction or cognitivist approaches to learning which value recall or speed of instructional progress. In the second wave or paradigm, improvements in communication would still most likely be presented in a work context, although the role of communication might shift from merely being efficient to perhaps creating a sense of belonging. Building upon theories from sociology and anthropology, the designer might identify opportunities to build team cohesion both in person and across distance (G. Olson & Olson, 2000), while also attending to the accuracy and efficiency of communication capability. In this context, the focus is still on improving work practices, but the social role of human actors is more dominant, and the agency of users to orchestrate their own experiences begins to be foregrounded. This might feel similar to most constructivist or learner-focused efforts in an educational context, where the agency and unique role of the student is valued alongside their ability to attain educational goals. In the third wave or paradigm, communication might be supported in a variety of contexts—from performing one's identity on SnapChat (McRoberts et al., 2017), to the "umbrella movement" that encouraged local democracy in Hong Kong (Kou et al., 2017), to the ability to communicate with one's romantic partner across continents (Sengers et al., 2005), to supporting communication among sex workers in order to identify bad actors (Strohmayer et al., 2019). In each of these contexts, the meaning and importance of communication might differ, resulting in contextually, socially, culturally, and interactionally-bound differences in design, adaptation, and use. This work may require the researcher to take on an activist role by attending to power differences, marginalized communities, or even issues of policy or illegal behaviors. In this context, the subjective qualities of interpretation, experience, and embodiment are foregrounded, with other elements such as technical feasibility, efficiency, or fidelity assumed to be present. This type of work is rising in prominence in educational contexts, primarily in relation to underrepresented groups or social justice, where the lived experience of learners is valued on its own merits and not just in relation to imposed standards.

In summary, HCI as a field can be seen as distinct from, yet related to UX design practice. HCI scholarship includes conceptual and methodological contributions from a range of disciplinary and epistemological perspectives, each of which is limited in scope, generalizability, and resonance with the complexity of everyday life. It is in the cross-section of these approaches—from computation, technological capability, and humanism—that the user and their needs can be identified and acted upon.

4. Building Connections to Relevant Instructional Design Scholarship and Concepts

As the previous section describes, HCI scholarship exists across a range of disciplinary and epistemological perspectives, which have been continuously reinforced and extended over the past three decades. This pattern of disciplinary inclusivity and translation is substantially different from the relatively isolated intellectual position of the LDT community over the same period (see Smith & Boling, 2009, for an example of this isolation in relation to design terminology and theory). Thus, while the LDT community has focused largely on issues relating to design process (see Branch, 2009; Gibbons et al., 1996, for some of these historical roots), the larger design community—and by extension, HCI scholars—have sought to create and disseminate design methods. ADDIE and its many derivatives focus on an overarching theory of praxis (Branch, 2009), while design disciplines more broadly construed (and as adopted in HCI, often) focus on the idea of method (Gray, 2016). This is evident through supporting texts (B. Martin & Hanington, 2012) and through a focus on method development in the HCI literature, although not always with successful adoption in practice (e.g., Roedl & Stolterman, 2013). While traditional views of theory and knowledge still tend to dominate LDT scholarship and practices, there is increasing engagement with other disciplinary communities such as HCI, particularly in the learning sciences.

I provide a brief comparison of process "stages" commonly used in LDT and methods that are commonly in use in HCI and UX practice in Table 2 as an example of this difference in language. While ADDIE is inherently limiting (see relevant critiques from Boling & Gray, 2014; Smith & Boling, 2009), drawing parallels between disciplinary perspectives is useful in highlighting the methods-focused language of UX across a range of potential design moves. The rich array of

methods used opportunistically across multiple design "phases" or "stages" also indicates a particular focus on the lived experience and context of everyday users across the design engagement that is not easily captured in a typical ID phase or method (e.g., learner analysis; Gray, 2015). Much of this richness of method is the result of the stronger modern alignment of HCI and UX practices with methods developed across numerous design disciplines (see B. Martin & Hanington, 2012, for a widely-adopted compendium of these methods), as compared to the relatively weak notions of design that are common in LDT (Smith & Boling, 2009). These views of design and design process have the potential to diverge in unproductive ways—as instructional designers seek to work with UX or HCI practitioners—if they are not recognized and reconciled. Part of this reconciliation is a further engagement in the research-practice divide and the differing definitions and conceptual vocabulary that describes design activity. This dialogue and conversation is still in nascent stages in the HCI community (Brier et al., 2017; Gray et al., 2014; Reeves et al., 2018), and is in its beginning stages in the LDT community (Boling et al., 2017; Gray et al., 2015; Smith & Boling, 2009).

Table 2

Brief Comparison of Process Language from Instructional Design With HCI or UX Methods/Concepts

ID Process Stages	Examples of HCI or UX Methods or Concept [a]
Analysis	User research (as an umbrella term) • Personas (Marsden & Pröbster, 2019) • Scenarios • Contextual inquiry (Beyer & Holtzblatt, 1998) • Ethnographic engagement • Interviews

Design
 	
Development
 	
Implementation
	• Prototyping (Lim et al., 2008)
	  ○ Sketching
	  ○ Wireframing
	  ○ Medium to high fidelity
	
	• Problem framing (Dorst, 2015)
	• Probes (Wallace et al., 2013)
	• Deployment studies (Chilana et al., 2011)

Evaluation	User testing (as an umbrella term) • Usability testing (Dumas & Redish, 1999; Reeves, 2019) • Cognitive walkthrough (Wharton et al., 1994) • Experience sampling (Hektner et al., 2007) • Wizard of Oz (Dahlbäck et al., 1993) • Experience prototyping (Buchenau & Suri, 2000)

[a] Any methods not directly referenced can be found in compendia of methods such as the work of B. Martin & Hanington (2012).

Following on from this contrast between process and method, there are also larger vocabulary misalignments that make movement across and within HCI and LDT disciplines problematic. While this is a known issue relating to transdisciplinary research and practice (Blevis & Stolterman, 2009; Gray & Fernandez, 2018), recognizing areas of

overlap and disconnect is an important starting place to building knowledge at the inter- and trans-disciplinary levels. As noted in Table 3, there are some areas of conceptual alignment among HCI/UX and LDT. For instance, both fields have used Dewey's notion of pragmatist aesthetics (e.g., Dewey, 1934/2005) to guide user/learner experiences, and both have a range of scholarship types with differing standards of rigor, differing outcomes, and different potential use cases. There are also areas with potential for alignment which, if undertaken without epistemological investigation, could result in false equivalency. For instance, while principles and best practices from LDT can easily be found in Löwgren's (2013) notion of intermediate-level knowledge, drawing an equivalency without attending to overarching notions of design knowledge and the relationship of these knowledge types to theory or precedent knowledge could result in improper conclusions. Finally, there are areas where each field has gaps that are well-covered by other fields. For instance, the use of participatory design and co-design approaches in HCI/UX has facilitated new modes of engagement with end users that is not present in traditional LDT scholarship. Similarly, the focus on learning and instructional theory in the LDT community does not have a strong equivalent in the HCI/UX community. In this latter case, we might probe historical examples to see where current opportunities might lie. For example, in the early days of desktop computing, Carroll and colleagues generated the "training wheels" model of instruction to encourage active exploration and early failure (Carroll & Carrithers, 1984), leading to the theory of minimalist instruction. Although this theory was introduced in an HCI context, it only had a lasting impact in the LDT context, aside from a brief reintroduction by a recent student of mine in relation to mobile onboarding experiences (Strahm et al., 2018). Thus, we can see the barriers between these concepts—and their potential for uptake in the alternate disciplinary context—as permeable, but requiring translational effort and awareness of the knowledge production norms of all relevant communities.

There is also a potential for alignment in a discussion of research methods more broadly. While multiple forms of research design are common, both in education and in HCI contexts, there are notable differences as well (see J. S. Olson & Kellogg, 2014, for an overview of research methods for an HCI audience). While LDT conceptions of research are primarily attached to formative and summative evaluation or related to patterns of implementation or adoption, HCI and UX researchers view research approaches more broadly in ways that may seem diffuse or unrecognizable as research to the LDT community. Drawing from Table 2, HCI researchers commonly use intermediate or final prototypes to elicit user feedback, but the temporal positioning of these engagements can vary broadly. For instance, a probe might be used as a means of identifying situational or contextual characteristics of user groups—a material artifact that can then engage users in sensemaking that is valuable for further work. One example of this is Chatting and colleagues' (2017) use of mobile phone sensors to create customized probes to interrogate family socializing and interaction practices and inform further research and technological development. While the probes themselves look complete, they are merely props through which to gain user involvement and feedback. In contrast, deployment studies can be used to gain summative feedback on the creation of a designed system by end users. But this need not be in the service of a "shippable" product. As an example of the indeterminacy of even a final product, Odom and colleagues (2019) created a highly polished sound system called Olly that was deployed into users' homes for an extended period of time. This system was intended to engage users in considering concepts of "slowness" and data, with the goal not of finalizing a system for production, but rather as a means of creating an interactive vocabulary to engage with in future design work. These two examples of probes and deployment materials have much in common and serve as two examples of research through design (RtD)—whereby the researcher/designer studies their own practices of both creation and engagement with users to enrich foundational concepts and vocabulary for future work. While there are some parallels with RtD and design-based research (DBR) common within educational research, the epistemological traditions that allowed these approaches to emerge in HCI and LDT, respectively, are quite different. While DBR is intended primarily as a set of design activities with scientific outputs (i.e., theory generation) as a goal, RtD originates in the practice of art and design, and does not generally result in the generation of theory. Instead, RtD results in a more situated and phenomenologically-aware set of practices and vocabulary, which may also then point to opportunities for the generation of theory (Bardzell et al., 2015).

Table 3

ID or Educational Research Concept	HCI or UX Concept
Learning as aesthetic experience (Parrish, 2009, 2013)	Technology engagement as aesthetic experience (Wright & McCarthy, 2004)
Design-based research (Wang & Hannafin, 2005) + Design cases (Boling, 2010)	Research through Design (RtD) [a] (Zimmerman et al., 2007)
Study of design practices (Boling et al., 2017; Boling & Gray, 2014; Gray et al., 2015)	Practice-led research (Kuutti & Bannon, 2014)
Principles, best practices, and formative research (Reigeluth & Frick, 1999)	Intermediate-level knowledge (Löwgren, 2013)
N/A [b]	Participatory design (McCarthy & Wright, 2015) and Co-design (Sanders & Stappers, 2008)
N/A [b]	Critical design (Bardzell & Bardzell, 2013), speculative design (Dunne & Raby, 2013; Elsden et al., 2017), and design fictions (Blythe, 2014; Lindley & Coulton, 2016)
Learning and instructional theory (Reigeluth, 2013)	N/A [b]

[a] While RtD is aligned with DBR, the aims and design knowledge gained through RtD varies substantially from common DBR implementation due to underlying understandings of design theory and design knowledge.

[b] This implies that there is no strong intellectual tradition, although isolated examples may exist.

Table 3 also provides potential insight into substantial research gaps in the LDT space, and narrower or different conceptual gaps in the HCI or UX literature. I wish to call attention to two specific areas where there is almost no research presence: (a) participatory and co-design approaches, and (b) critical and speculative work. Participatory design (PD) and co-design are philosophically aligned methodologies that aim to enable everyday people to engage in design processes in ways that value their lived experience and flatten traditional structures of power or hierarchy. PD in particular has activist and social justice roots in 1970s Scandinavia; as a result, PD seeks to not only identify stakeholders that may have a "stake" in the system being designed but also to identify those individuals who may not yet have a seat at the table (Simonsen & Robertson, 2012). In HCI contexts, participatory approaches have been used to engage marginalized populations such as rural LGBTQ+ youth (Hardy & Vargas, 2019), more fully involve a range of individuals in citizen science work (Qarooni et al., 2016), and include women's voices in the design of breast pumps (D'Ignazio et al., 2016). The vocabulary of participation and inclusivity is present in the broader educational literature, but is discussed infrequently in an LDT context, and is almost completely lacking in explicit support through design processes and methods. In an extension of this critically-oriented approach to design activity, critical and speculative work has also risen in prominence in HCI scholarship as a way of identifying potential future social impact, calling

attention to inequity, and encouraging dialogue and social activism. In HCI contexts, this research approach has been used to interrogate gender and design through an analysis of the Menstruation Machine (Bardzell et al., 2015), foreground worker rights and the limits of the quantified self (Toombs, 2014), or even to investigate how lawn-mowing robots could be caring members of a community in the year 2040 (Toombs et al., 2020). While some critical and speculative fiction research might appear trivial or even silly, its goal is to uncover, displace, or bring into language structures that designers need to attend to now and in the future. This space is largely unexplored in an LDT context, even while privacy threats are rising in areas such as learning analytics, which could be productively explored through creative and defamiliarizing methods such as critical design and speculative design fictions (Gray & Boling, 2016).

5. Toward a Definition of Learner Experience (LX) Design

Building on the disciplinary perspectives—including both gaps and opportunities—of LDT and HCI/UX, there are noticeable areas of overlap in perspective and approach which may indicate conceptual boundaries for a future Learner Experience (LX) design role. As is already the case with UX design, job roles and titles have quickly outpaced the academic community and means of formal preparation (Kilgore, 2016). Thus, while I cannot propose to define the field in relation to its present or future form, I do wish to offer a set of guiding principles which may be worthwhile to consider as practitioners and academics alike shape the field and offer formal educational preparation in the future.

As a starting point, I come from a combination of design, education, and HCI traditions, and view design activity as inherently always already about learning. Whenever we engage with what Nelson and Stolterman (2012) term the "not-yet-existing," we must rely on our prior experience and our ability to learn something new in order to make sense of and use that new designed artifact. Thus, the drive in UX design to make experiences feel "intuitive" could merely be seen as a restatement of learning outcomes and objectives. In this spirit, I propose some existing areas of alignment that could be exploited as a conceptual pathway towards LX:

1. Designing for aesthetic experience, not just recall or performance in traditional framings. Rather than focusing primarily—or only—on learner performance through measures which are presumed to be objective, build upon notions of learner agency and lived experience from critical pedagogy and aesthetic experience to encourage the creation of meaningful, situated, and memorable learning experiences. Rather than assuming the only philosophy of instructional design to be the creation of "efficient, effective, and appealing" experiences (Merrill et al., 1996), consider other alternative philosophies that may resonate more with the lived experience—socially, culturally, and experientially—of particular groups of humans that wish to learn.
2. Considering the acquisition and performance of knowledge in real life/authentic contexts (cf. plans and situated actions; Suchman, 1987). Rather than assuming that education or learning must occur in certain settings or through predictable learner and instructor roles, identify opportunities for learners to engage in processes of self discovery, co-construction, and empowerment. This requires investigation into the lived experiences, mental models, systems of structural oppression which learners might exist within, and the identification of learning systems that address relevant gaps or opportunities in ways that resonate with this subjective experience.
3. Queering, reformulating, and empowering the user/learner while attending to the impact on the larger social, cultural, and environmental context(s). Rather than assuming that learners have similar characteristics and experiences, which often advantages certain types of students in powerful structural ways, identify mechanisms whereby learning experiences can value unique and subjective learner qualities. By recognizing alternate modes of learning—and their potential for broader social outcomes—new classes of learners that have been traditionally disenfranchised may find the space to thrive and become empowered.
4. Framing design as inherently situated, conducted through a designer's character and knowledge, and viewed as a "third way" or specific epistemological perspective that allows for inquiry and action. Rather than positioning design activity as monolithic and defined primarily as "modifications to the model," identify ways in which the designer assumes responsibility for the near- and long-term social impact of their work (Gray & Boling, 2016) in ways that are reflexive, situated, and guided by multiple forms of design knowledge that may arise from multiple disciplinary traditions and epistemologies.

If design is really already about learning, how can LX designers help, and what should the boundaries of their practice be? Should LX designers deal primarily with situations where the learning is unintentional, unstructured, or informal and leave traditional instructional designers to deal with formal learning design challenges? Should LX become an umbrella that is a superset of traditional ID practice, offering new space to play and explore at the intersections with UX and HCI? Wherever the field and the future role of LX lands, this chapter should facilitate an interrogation of knowledge types, disciplinary perspectives, and epistemological perspectives across HCI and LDT communities that will be useful in reading the other chapters in this book.

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Theories of Change in Learning Experience (LX) Design

Keith Bowen, Karin S. Forssell, & Soren Rosier

Learning Experience Design   Theory of Change   Logic Model   User Experience Design   Design Process

Hypothesis Testing

Designers' theories about how people learn are the keys to impactful educational design. While much effort and attention is appropriately paid to usability in the development of educational tools and materials, the centrality of learning theories is often underappreciated. Learning theories, in combination with considerations of usability, form coherent theories of change. Theories of Change frame how designers expect to shift learners' knowledge, skills, and abilities. They play out in the features included in digital learning tools and in the activities chosen for learners in technology-enhanced experiences. They are critical to recognizing whether a design is effective. The clearer the theory, the more specific and measurable the indicators; and reliable, focused measures are key to ensuring that a design is working as planned. Additionally, good measures can transform data into launchpads for design iteration. Aligning learning theory, design, and measures, however, is easier said than done. Through illustrative cases of two learning projects, this chapter gives readers useful frameworks and intuitions to approach this process. Designers will be better prepared not only to create effective experiences, but also to communicate their impact to a range of stakeholders including learners, teachers, buyers, and funders.

> ## Author's Note
>
> All three authors contributed equally to this chapter. Names are in alphabetical order.

1. Introduction

Theories about how people learn should drive the process of designing learning experiences. Those theories that designers hold about how learning happens help them to frame their early investigations into a specific learning problem, their successive iterations in learning design, and their repeated testing with targeted learners. Why does this matter? In a world where educational challenges are vast, historically entrenched, and highly complex, such "theories of

change" help designers avoid scattershot innovation, serve as powerful anchors for the design process, and help answer the fundamental process questions "Where do I start?" and "How do I know if I'm making progress?"

Working with students in the Learning, Design & Technology (LDT) master's program at Stanford University's Graduate School of Education (ed.stanford.edu/ldt), we have found that the degree to which students invest in developing and anchoring their design work in well researched and clearly articulated theories of change consistently predicts success. Such theories of change are powerful tools to clarify and guide our work in learning experience (LX) research and design.

2. Theories of Change

The concept of a theory of change is borrowed from the world of program evaluation. It can be used to plan, communicate, manage, and assess interventions. Philanthropists, government agencies, and policy-makers use theories of change as lenses to examine the apparent effectiveness of early-stage interventions for improving lives and livelihoods (e.g., Brest, 2010; California Department of Education, 2019).

Evaluation expert John Mayne notes that theories of change "represent how and why it is expected that an intervention will contribute to an intended result" (2015, p. 127). They can be seen as one kind of logic model. Logic models outline the inputs, activities, outputs, and outcomes that are intended (McLaughlin & Jordan, 2004). Importantly, theory-based logic models (theories of change) emphasize not only "what" will be done but "why" (Mayne, 2015; W. K. Kellogg Foundation, 2004). The approach provides insight into the different assumptions that are embedded in a strategy and should drive user testing. As learning experience designers, the focus on theory prompts us to build on existing research on how people learn. Because new information may challenge assumptions along the way, we encourage designers to revisit their theories of change often and to update them in light of new insights.

In the context of LX design, we like to illustrate the Theory of Change through a simple graphic that shows the learner, the learning outcome, and the approach that informs activities (see Figure 1). Although there are many more details that can be added (Mayne, 2015), this is a useful starting place for designers. Our focus on the learner is key to our learner-centered design philosophy. While keeping the learner at the center, we also consider the contextual factors that make learning possible (Papert, 1987). Because we hope that the outcome is an improvement, we've chosen to illustrate the change with an upward slope. This clarity of purpose helps inform both the design of prototypes and research metrics.
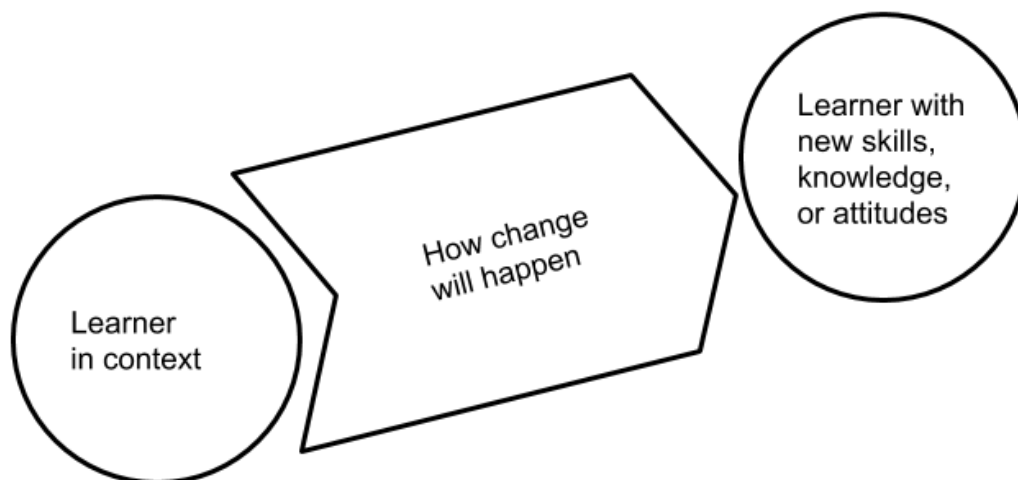
Figure 1

Theory of Change

2.1. Theories Driving LX Design and UX Design

This approach to theories of change helps highlight key parallels and contrasts between user experience design (UX design) and learning experience design (LX design). Both are guided by theories that are well researched, developed, and tested. There is some overlap between the theories that guide both disciplines, but generally they are drawn from different traditions and can be used to formulate different questions.

In the case of UX design, theories from the field of user research, including theories on attention and perception, guide designers in the development of the whole user experience. They apply to educational products and experiences and impact learning, but they also apply more broadly to all products and user experiences, helping to answer core questions such as whether a product is easy to use and will sustain user engagement.

LX design is similarly informed by theories, but, in this case, researchers and designers study and leverage insights from specific theoretical frameworks that focus on how people learn, e.g., behaviorism, cognitivism, and a range of socio-cultural theories, and theories that explain core mechanics of learning at more granular scale, such as worked examples, contrasting cases, and embodied cognition (e.g., Schwartz et al., 2016).

In the Stanford LDT program, we have observed that novice designers tend to favor intuitive outcomes of engagement, likability, and usability to measure progress. All of these measures, while important to user experience (UX) and eventual product viability, should not be the sole focus of early testing. When developing tools intended to foster learning, it is paramount to explicitly define and test the learning theories on which those tools depend through deliberate learning experience (LX) design.

2.2. Key Questions for LX Design

In order to develop and communicate an effective theory of change for learning design, we need to have answers to three key questions:

- Who are the learners? The more we know about the learners, their knowledge, and their context, the better our insights about how to design something that will work for them. Are they middle school students? Parents of young children? What do they already know or think they know? What is the context of their learning? When do they learn and where? Do they have broadband? Android phones? These questions will impact the stakeholders interviewed, the users tested, and the contexts observed in field studies. Once learners are identified, some designers find it useful to document their relevant traits in the form of fictitious "personas." These constitute our first hypotheses of which learners and which of their traits should most drive our design work.
- How will they learn? Our ideas about what makes a learning experience effective will play out in the features included in digital learning tools. These features should deliberately draw upon documented learning mechanisms from the learning sciences (Nathan & Alibali, 2010). In the field of LX design, these might include embodied learning, personal connections, independent pacing, just-in-time delivery, or emotional safety, just to name a few. They guide the activities we create for students.
- What are the learning goals? LX design is directionless without clearly articulated outcomes and measures. If we don't know what we're aiming for, how can we know whether we're hitting the target? Sometimes those outcomes are long-term, which makes measuring the learning difficult. But indicators of progress toward those goals can be developed, and over time specific measures can be identified. The clearer the theory, the better the indicators we can measure. Having reliable, focused measures is key to ensuring that a design is working as planned; more importantly, they transform data into launchpads for design iteration.

LX designers seek to help learners by understanding how they learn and help teachers to identify and measure their students' progress towards specific learning goals. Unfortunately, we have found that when connections between learning theory and design are tenuous, projects sputter and design iterations are haphazard. However, when theory and design are aligned and well-articulated, LX designers have a roadmap to guide the development, analysis, and refinement of learning designs.

In this chapter, we present the stories of two digital learning tools that were informed by very different theories of change. In Section 3, we describe Bounce (a math game tool), and, in Section 4, we describe Prevention Begins With Me (a tool to educate about AIDS prevention). These examples are drawn from projects created by past students in the LDT master's program at Stanford University. They were selected as cases that illustrate effective testing of both LX and UX assumptions, driving modifications in design that resulted in products enjoying widespread use, documented efficacy, and longevity, which are testament to the design process. While their target learners and contexts are radically different, both projects shared a fundamental commitment to the development of strong, well-informed theories of change to guide deliberate, calculated iteration. This chapter documents the genesis of both projects and the theories of change that drove their user testing, iteration, and evolution into mature products with impact.

3. LX Design in Motion Math: Bounce

Bounce is one of several math games by Motion Math, now part of the i-Ready Learning Games suite (https://edtechbooks.org/-Hfv). Motion Math designs games to engage students in exploring a variety of foundational math concepts in a way that is both engaging and instructive. By mapping abstract concepts onto physical interactions, Motion Math aims to connect abstract ideas with concrete intuitions. Bounce was developed with a mission to help more children understand fractions.

3.1. The Need

In 2010, Motion Math Games Founders Gabriel Adauto and Jacob Klein were looking for an opportunity to set young learners on a successful path in math. Asking teachers to name the most difficult concepts to teach and for children to understand, they learned that fractions are a stumbling block for many elementary students. A review of the literature confirmed that poor or incomplete understanding of fractions is associated with struggles later on. For example, learners who have only a superficial understanding of fractions often find it difficult to wrap their heads around algebra (Booth & Newton, 2012), a subject that has long been a gatekeeper for college readiness (Spielhagen, 2006).

So why are fractions so hard to teach? This problem was not driven by lack of access to curriculum since virtually all comprehensive elementary school math textbooks cover fractions (Alajmi, 2012). However, understanding the magnitude of rational numbers is inherently difficult and their many symbolic representations create confusion (Siegler & Lortie-Forgues, 2017). The Motion Math team wanted to create a tool that would help students develop a strong foundation with fractions and a positive experience in learning mathematics.

3.2. Theory of Change

For Adauto and Klein, translation turned out to be an important concept. By reviewing this body of learning sciences research, they discovered early on that one of the most effective approaches for mathematics learning is to make connections between different representations of a concept. For example, SimCalc software (https://simcalc.sri.com/) shows learners what an equation means in a table of values, a graph, and an animation. As the learner changes a value in one place, the other representations are updated to match. This software, with teacher training, had been shown to substantially increase learners' understanding of algebraic concepts (Roschelle et al., 2010). Inspired by research like this, the team of LDT students decided to help learners translate the symbols of fractions to concrete representations of physical objects from the real world.

In early grades, translating between concrete to abstract is often done through objects known as manipulatives. Manipulatives are physical objects like blocks or tokens or pie pieces that make the symbolic numbers meaningful. Interacting with objects is one of the ways that learners make sense of math problems (Martin & Schwartz, 2005). This is one example of what has been referred to as "embodied cognition" (Wilson, 2002), the notion that one's thinking is tied to and enhanced by the body's physical interactions with its environment.

Unfortunately, the use of blocks can also lead learners to misunderstand the nature of fractions. When the examples are always given as parts of a whole, for example, learners often get stuck when they're later asked to multiply or divide—it

is more helpful if the fractions are seen as parts of a group (Ball, 1992). When devising a learning plan on a topic, it is important that designers choose a range of examples that avoid some of the traps that can box learners into unproductive ways of thinking. And it's critical to assess whether the students are making the correct connections along the way. Blocks, like all manipulatives, are limited in the feedback they provide.

To sidestep these learning pitfalls, guided practice can offer learners meaningful feedback to develop their expertise (Ericsson et al., 1993). To encourage practice, the challenge should be at the appropriate level. An activity that matches one's competence to the task's difficulty level can lead to a pleasant challenge or state of flow, the feeling of losing oneself in an activity (Csikszentmihalyi, 1997). Many games induce this state when they challenge players, while also providing the resources they need to succeed (Gee, 2005). Interactive computer games can provide guided practice with meaningful feedback in a way that matches the learner's ability and adapts to their growing mastery.

In the late 2000s, a new set of devices transformed the opportunities for digital-physical manipulation. Adauto and Klein realized that sensors in the new Apple iPhone[1] would allow learners to use their bodies to interact with a range of representations of mathematical concepts. In addition, computers can generate tasks based on past performance, to create appropriately challenging prompts. With the knowledge of the device's potential, Adauto and Klein planned to design an engaging smartphone app that would help learners understand what fractions really mean. The challenge was to allow learners to interact with a variety of representations—including fraction symbols, pies, decimals, percents and number lines—that built an accurate foundation to support them in their future math learning. See a simple illustration of this theory of change in Figure 2.
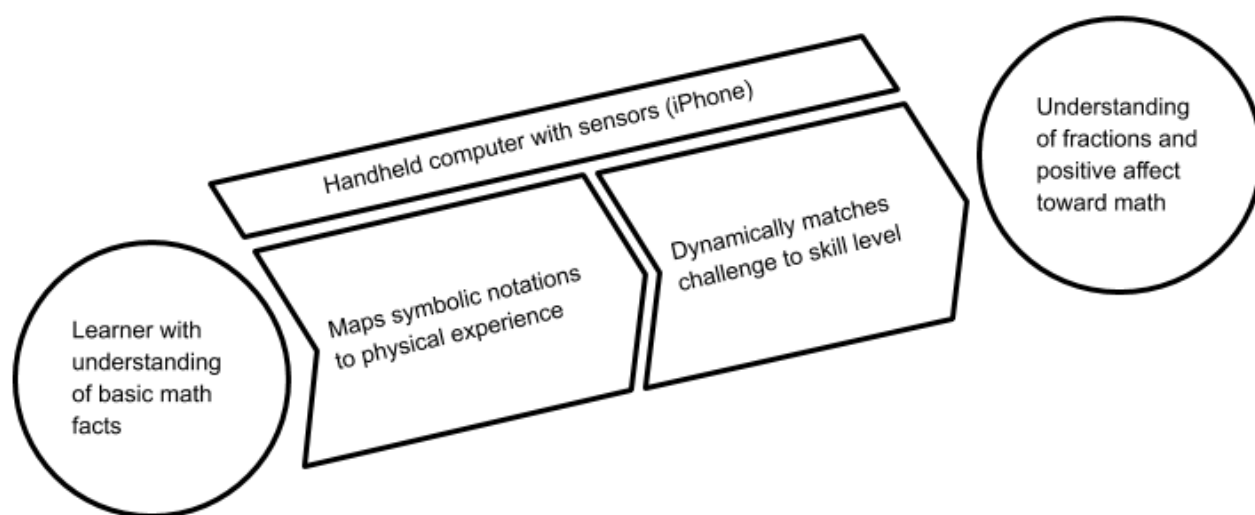
Figure 2

Theory of Change Applied in the Game Bounce

The team started to prototype a game that would map different representations (pies, percents, decimals) to a number line. Through tilting the phone one way or another, learners would "bounce" a fraction on a number line. The vision was to create a series of fraction-mapping tasks that could be dynamically updated in a game. The game would take learners through levels that explored relationships between different types and representations of fractions and number lines with different ranges. A screenshot of the final game is presented in Figure 3.
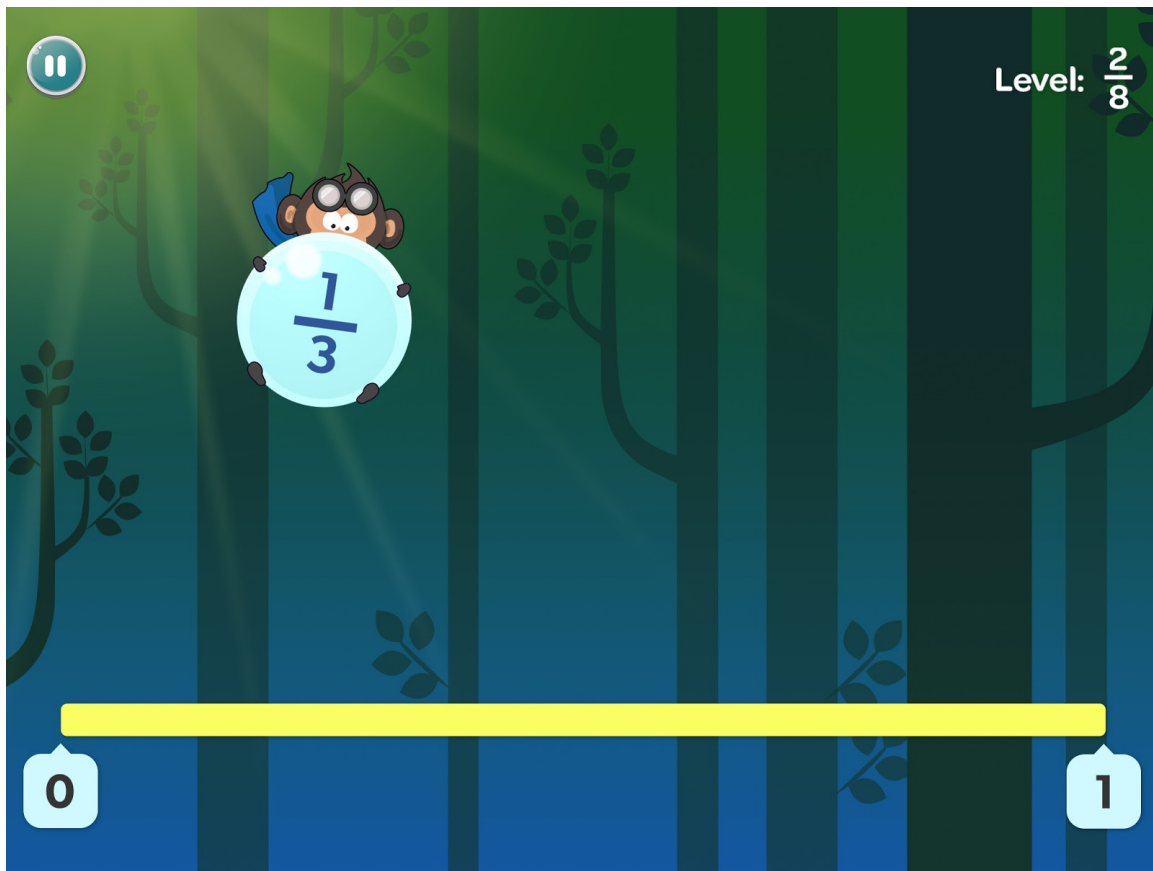
Figure 3

Fractions in the Game Bounce

Note. In this screenshot from the game Bounce, the learner is asked to tilt the smartphone to place the fraction 1/3 on a number line representing 0 to 1 (Motion Math, 2019).

3.3. Testing Hypotheses

There were many ways that this solution could fall short, if not well-designed. A look back at the theory of change shows several testable assumptions. Did the physical interactions work on this new technology? Could the team build an app that was appropriately challenging and, therefore, induce a flow state? Was the feedback appropriate and helpful? And ultimately, were the learners successful in manipulating fractions, developing a positive affect, and persisting in learning math? These questions, derived from their theory of change, led the team to a series of prototype tests.

3.3.1. Did the Physical Interactions Work Using this Technology?

A key assumption in the theory of change for Bounce was that physical movements would aid in understanding math. The first question, then, was whether the movements would work as planned on a digital platform. The team first used a paper cardboard mock-up with a nickel on a string to represent the bouncing ball, which learners could manipulate with ease. However, transitioning to an interactive app presented new challenges. Smartphones were brand-new at the time, and most people had a mental model of clicking on a screen. Early app testing convinced the team that, while tilting a device to interact with a game was novel and unintuitive to some, it was a promising modality that worked well once understood. As a result of this early testing, the designers developed a brief tutorial showing learners how to tilt to aim the ball before they moved on to the first fraction.

3.3.2. Was it Fun?

Another key assumption was that the game would keep learners engaged. If the game induced a flow state—if it was fun—it would propel the development of their mathematical intuitions. The goal would be to find the right level of challenge. To test this, they had kids in 2nd through 6th grade play a simple version of the game. Through these learner tests, they quickly identified that the game was at an appropriate level of challenge for 4th- and 5th-graders. Stakeholder interviews with teachers and curriculum standards helped refine the specific learning goals for the game.

It was important to the team that the mathematics were endogenous to the game, rather than a gateway test that allowed users to advance to the next level (Malone & Lepper, 1987). But would interacting with Bounce actually develop kids' interest and ability in math? Yes, measurably so. In 2013, a school-based study of Bounce[2] found that learners showed better understanding of fractions, better attitudes, and willingness to complete more math problems after using Bounce than after regular instruction (Riconscente, 2013). But, long before that study's results, the team had evidence that they were on the right track through observations of children playing early versions of the game. Though early prototypes had fewer levels and less polished graphics, the learners smiled and laughed while playing. One girl called it "a kid's dream of school" (Motion Math Games, 2010). They wanted to play more.

3.3.3. Was the Feedback Actionable?

An important reason for using a digital rather than physical tool was the ability to provide timely and actionable feedback. The team invested a great deal of effort into getting the "hints" right. Powerful scaffolding (Puntambekar & Hubscher, 2005) should include ongoing diagnosis and graduated assistance and should fade out if no longer needed. Through cognitive task analysis interviews with expert educators, the team developed hints that provide progressively more help to guide learners (see Figure 4). User tests were then conducted with learners to identify a small set of useful hints.
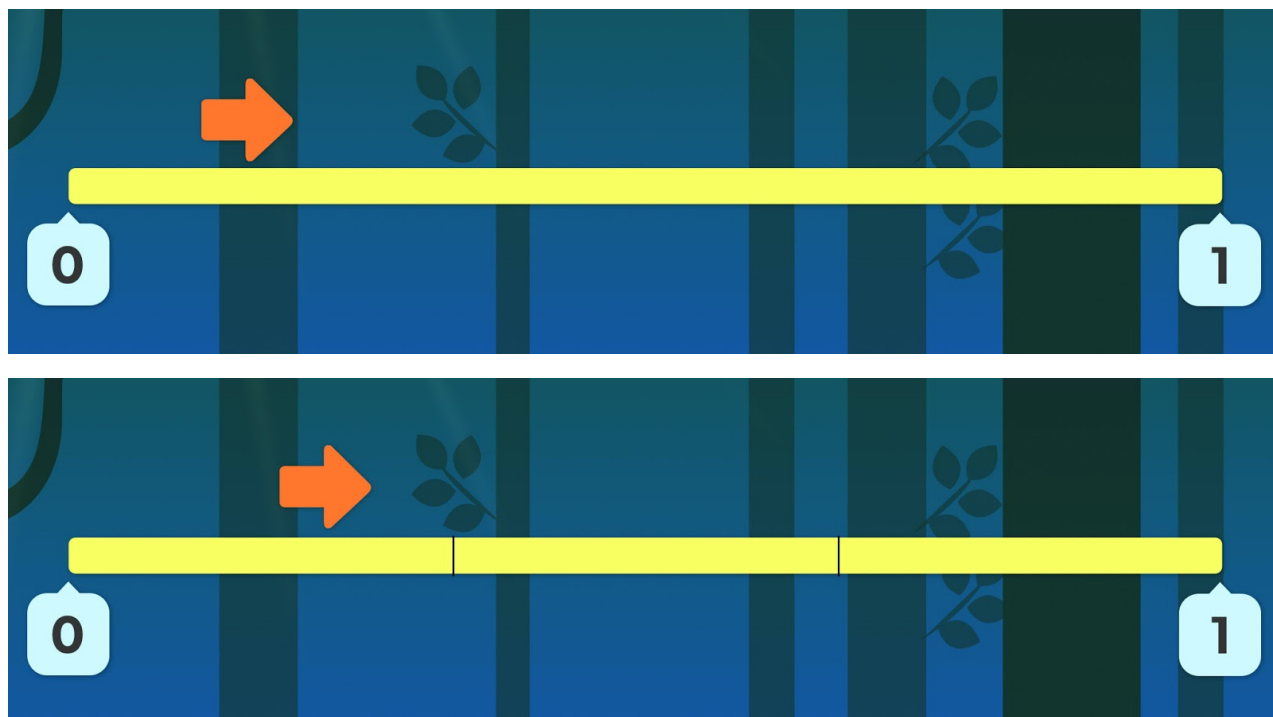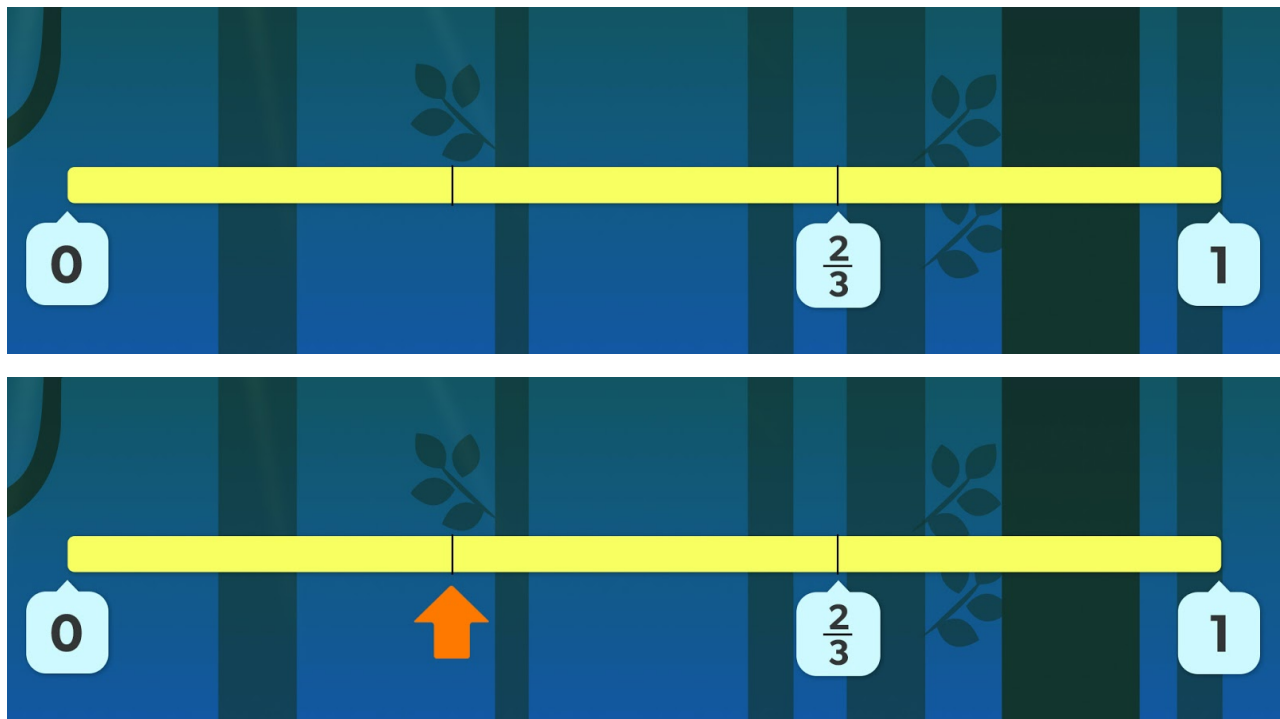
Figure 4

A Number Line in the Game Bounce

Note. These screenshots illustrate how learners are shown progressive hints to guide them toward the correct placement of the fraction 1/3. If not successful, learners will be shown the correct answer before going on to the next problem (Motion Math, 2019).

Through focusing on questions derived from their theory of change, the Motion Math team was able to identify and validate their assumptions early. Their process generated insights to inform their key game mechanics and learning targets, leading to an engaging and effective game.

In the next section we present a tool designed to solve a very different learning challenge. As with Motion Math Bounce, the design and development of TeachAids Prevention Begins With Me illustrates the value of a well-articulated theory of change.

4. LX Design in TeachAids: Prevention Begins With Me

TeachAids (teachaids.org) is a non-profit organization located in Silicon Valley that develops technology-based education products to address persistent global health problems. Prevention Begins With Me[3], the innovative product that launched the organization in 2009, has been used to teach hundreds of millions of people around the world about HIV/AIDS prevention.

4.1. The Need

In 2007, national and international health organizations were struggling to find effective approaches to teach HIV/AIDS prevention in low-income countries. The need for education was overwhelming. In 2007, 33.2 million people around the world carried the HIV virus, and the number was quickly rising (UNAIDS, 2007). Ninety-five percent of those cases came from countries where deep and endemic poverty makes education on any topic difficult (Noble, 2007, as cited in Sorcar, 2009). Misinformation about the disease was rampant, and national and international leaders were eager for solutions.

What makes education on HIV/AIDS especially difficult is the range of cultural taboos on teaching topics related to intravenous drug use and sexual practices, especially homosexuality, pre-marital sex, adultery, and commercial sex work. In India, for example, the central government worked with national and international experts on the disease to develop an official HIV/AIDS curriculum, but many of the country's states banned it from public schools. To bypass the obstacles in schools, the government also developed mass media campaigns. Unfortunately, these also posed challenges as they lacked depth, could not be targeted to specific learners, and were very expensive (Sorcar, 2009).

4.2. Theory of Change

In the learning sciences, researchers and practitioners study and leverage insights from a range of theoretical frameworks that describe how people learn, e.g., behaviorism, cognitivism, constructionism, and others. In particular, socio-cultural theories of learning build on the recognition that learning is more than a solitary act performed by separate individuals and that learning is a social process inseparable from its cultural context. In 2006, TeachAids founder Piya Sorcar hypothesized that a fundamental barrier to effective education about HIV/AIDS was the range of cultural taboos related to talking about sexual practices, especially in India and other low-income countries (Sorcar, 2009). With socio-cultural learning theories in mind, Sorcar began an extended exploration of the teaching of taboo topics.[4]

Sorcar's design process aimed at testing a clear theory of change: that to teach HIV/AIDS prevention effectively, especially in culturally conservative countries like India, the program must be designed specifically to circumvent social taboos (Sorcar, 2009). This high-level theory of change is illustrated in Figure 5.
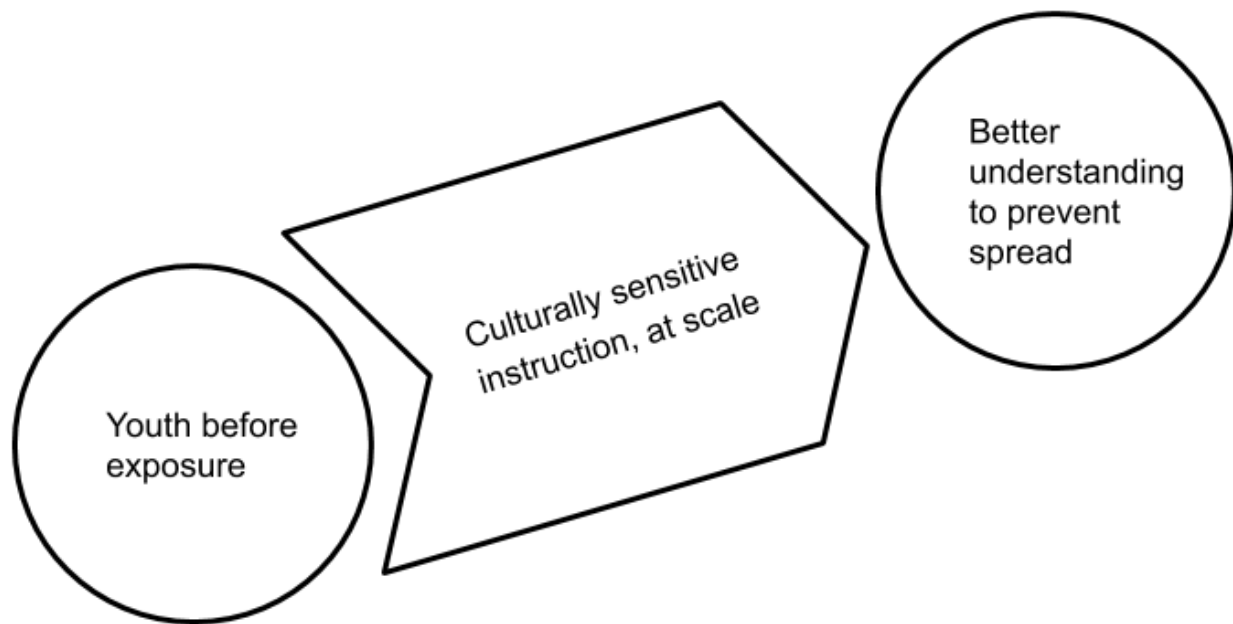
Figure 5

A Simple Theory of Change in Prevention Begins With Me

4.3. Preliminary Hypothesis Testing

The first phase of testing involved an extensive competitive analysis to understand the strengths and weaknesses of existing curricula and further understand what elements contribute to emotional safety. While competitive analysis is best known as a business technique for identifying weaknesses, gaps, and opportunities in markets (Fleisher & Bensoussan, 2015), it can also serve as a powerful early-stage tool for LX designers. In particular, before one has a prototype to test, analyzing existing products and even testing them with users to understand their shortcomings can provide critical insights to inform the theory of change that undergirds one's own designs. To understand the existing

solutions, Sorcar teamed up with a range of collaborators to conduct semi-structured interviews with young adults, schoolteachers and administrators in India, experts in public health and medicine, and others. The interviews were designed to map existing efforts to teach HIV/AIDS prevention, determine what students had gained from those teaching efforts, and identify which topics made them most uncomfortable.

To confirm and build upon insights from these interviews, team members also developed surveys through a process that went through several iterations to make them acceptable to administrators. Surveys were an important method that allowed private and anonymous written responses to culturally sensitive questions. About 200 Indian college students responded, providing crucial insights into their questions and misconceptions. Concurrently, in interviews with medical experts, the team developed its understanding of what young people need to know about HIV/AIDS prevention (Sorcar et al., 2017). This work uncovered several issues.

Testing students showed that misinformation about HIV/AIDS was widespread even after they had examined instructional materials. HIV/AIDS prevention is too often taught as a disconnected set of "DOs" and "DON'Ts", which puts stress on learners' cognitive capacity and makes retrieval difficult (Sorcar, 2009). Not only did learners have significant misunderstandings about the nature of the disease and its transmission vectors, but they tended to think of it primarily in moralistic rather than biological terms, associating it with behavioral practices generally condemned in their society. A focus on biology, however, provided an opportunity to address it as a standard topic in Indian schools (Sorcar et al., 2017).

Another challenge was the unwillingness of teachers to discuss the subject with their students. Sorcar found that, due to their discomfort, teachers commonly avoid discussing topics related to sex with their students. In one state in Northern India, teachers burned sex education materials in bonfires. Students also tend to be embarrassed by any discussion of these topics.

Learners' and administrators' reactions to various styles of illustration in existing materials showed that many were uncomfortable with more explicit visual depictions. A tension emerged between visual accuracy, which can be obtained through photos and detailed drawings, and the comfort of learners (Sorcar, 2009; Sorcar et al., 2017). Similarly, students were often more comfortable using metaphors and euphemisms than the more accurate but culturally objectionable terms.

4.4. Revised Theory of Change

Sorcar and her team used these insights from early research to develop a more nuanced theory of change (see Figure 6). This deep understanding of the problem inspired the features and frameworks that the team then proceeded to build and test.
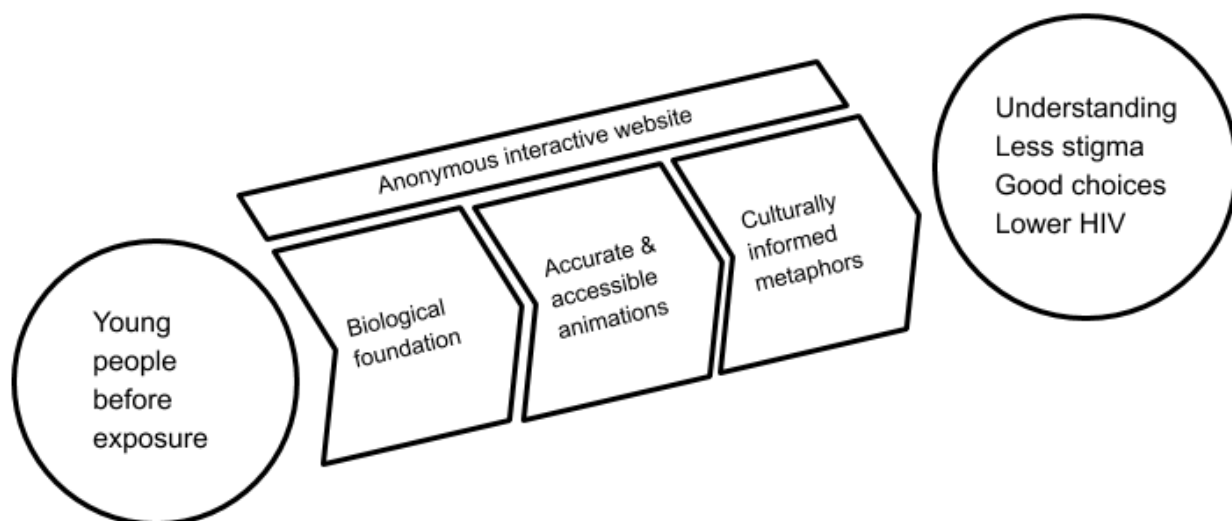
Figure 6

A Revised Theory of Change in Prevention Begins With Me

The design brief based on this theory of change featured an interactive website rather than live teaching, recall based on biology rather than morality, a visual treatment based on animations rather than live video, and description using comfortable verbal and visual metaphors rather than medically explicit imagery and language. The product also featured cultural, gender, and age affinity between on-screen characters and target learners to increase the sense of emotional comfort while learning about a culturally sensitive topic (see Figure 7).

Figure 7

Characters in Prevention Begins With Me

Note. This screenshot shows characters in Prevention Begins With Me. The design team carefully matched visual and voice characteristics of the animated characters in the program to those of its targeted learners. Designers created separate scenarios based on gender, with a male doctor and a male patient for male learners, and a female doctor and a female patient for female learners (TeachAids, 2019).

The choice of an interactive web site was driven by the desire for learners to study on their own and spare them social discomfort or public embarrassment. This approach also helped ensure uniformity, accuracy, and completeness in the presentation of information to all students. Importantly, the choice of a solution based on networked technology facilitated the design team's efforts to gather data on various aspects of student use, interaction, and learning, which the team then analyzed for formative evaluation of successive prototypes (Sorcar, 2009).[5]

4.5. Further Hypothesis Testing

As the team began to build out prototypes, they systematically sought feedback on how their designs were received by the target learners. The team began with low resolution paper prototypes, progressively refining them through PowerPoint slide decks and then through higher resolution computer animations. Using about 150 prototypes, team members answered a series of questions related to their theory of change: how comfortable learners were with different visual and verbal metaphors, which ones worked best to communicate accurate information, and which were most effective at building long-term understanding and retention (Sorcar et al., 2017).

4.5.1. Are the Visual Depictions Approachable? Are the Euphemisms and Metaphors Accessible?

Prior to the development of the first version of the product, the team conducted a detailed survey of targeted learners to test their reactions to various styles of visual depiction. The team was able to develop a series of animated drawings to communicate accurately without unsettling learners and school administrators (see Figure 8).
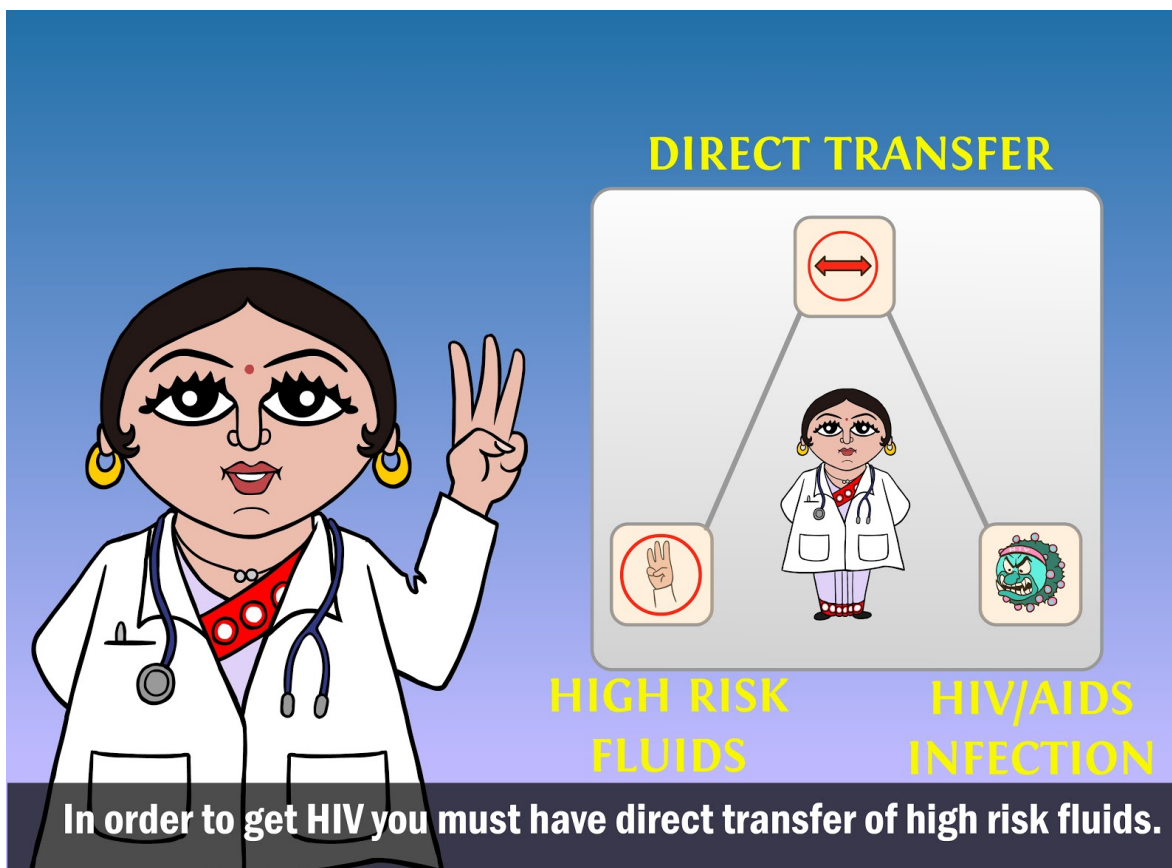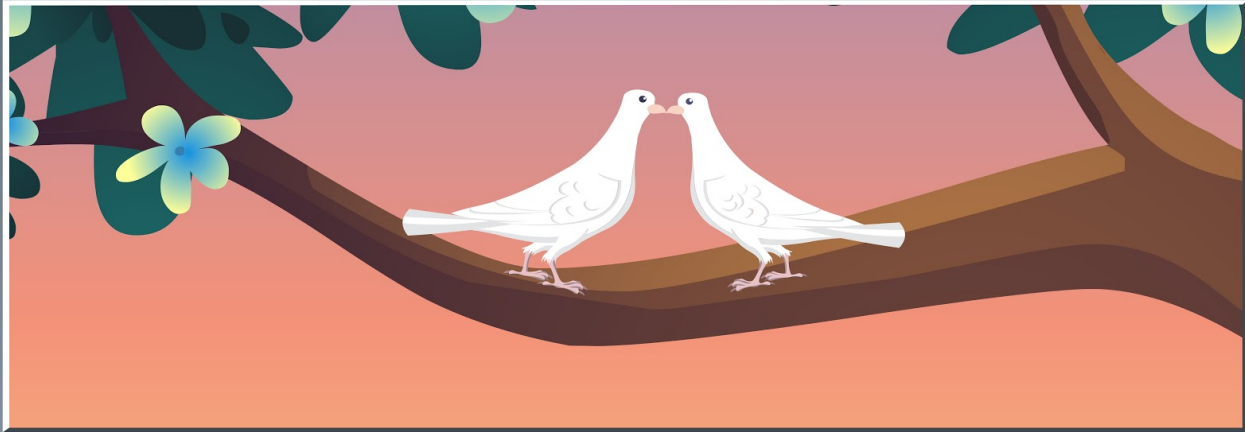

Figure 8

A Female Doctor in Prevention Begins With Me

Note. This screenshot illustrates a female doctor reviewing the 3-point mantra for possible HIV infection (TeachAids, 2019).

The team developed a series of culturally familiar verbal and visual metaphors and euphemisms. In one scene, rather than displaying a couple publicly kissing, the animation shows the couple coming very close to a kiss while the camera gently pans upward to a pair of pecking lovebirds, a Bollywood convention easily recognizable by target learners. Rather than present even a simplified depiction of physical intimacy, illustrators portrayed a woman sitting on a bed, dressed in a gown and surrounded by a traditional floral arrangement indicating that it was her wedding night (see Figure 9).

Figure 9

Metaphors in Prevention Begins With Me

Note. These screenshots illustrate how the design team for Prevention Begins With Me leveraged culturally sensitive metaphors and euphemisms taken from Bollywood movies (TeachAids, 2019).

4.5.2. Are the Students Learning From This Approach?

Once the curriculum had been developed to the point where it could be presented on PowerPoint slides, testing included formal learning assessments given before and after the experience to measure knowledge gains and changes in attitudes.

After the first complete version of the project, pre-post experimental studies with 295 students in the 11th and 12th grades showed statistically significant gains in their understanding of HIV/AIDS. In addition, stigma towards the disease was reduced and attitudes toward people with HIV/AIDS became more positive. For example, after the intervention learners were more likely to agree with the statement "It's okay to be friends with someone who is HIV-positive" and disagree with the statement "People with HIV/AIDS should not be allowed to work/study in public schools." Follow-up assessments conducted a month after the intervention showed persistence in the learning and attitude gains (Sorcar, 2009).

Thanks in part to this evidence of efficacy, the product has since been deployed in tens of thousands of schools throughout India and beyond (Sorcar et al., 2017). Over time, the theory of change has been further refined and now

includes partnering with celebrities to reduce stigma around the topic. The founders of TeachAids have partnered with more than two hundred organizations and adapted Prevention Begins With Me for use in over 80 countries around the world. Recently, the team has adapted the model in the development of a new product, CrashCourse, which provides students, parents, and coaches with the latest medical information about prevention and treatment of concussions.

5. Discussion, Implications, and Conclusion

For those designing educational solutions for learning challenges, this chapter is intended as a guide for answering the essential process questions "Where do I start?" and "How do I know if I'm making progress?" A designer's theory of change leads directly to features and interactions to test out. If the goal is to design a solution with the right activities to yield a particular learning output, early prototypes should be designed to deliberately test the learning theories underlying that solution. Progress should be measured via the prototypes' failure or success in reaching the desired learning outcomes.

Hypothesis testing is key to designing impactful interventions and can be continued past initial design to product viability. A theory of change is key to developing such hypotheses. In recent years, the value of hypothesis testing has been demonstrated by the startup business community. Perhaps most notably, Eric Ries, in *The Lean Startup* (2011), argues that hypothesis testing should drive early startup efforts. More recently, a group of Italian researchers performed a randomized controlled trial with 116 startup companies to test the impact of training company founders to use hypothesis-testing to drive their innovation. The trial found hypothesis testing improved business performance, frequency of pivoting, and company longevity (Camuffo et al., 2019). This mindset of using a theory of change to develop hypotheses was key to the long-term success of both Motion Math and TeachAids. In both cases, projects initiated by students in a master's degree program grew into mature products reaching millions of learners around the world.

A retrospective analytical account, such as this present one, can give the misleading impression that UX and LX design processes are linear and tidy. They generally are not. Rather, design teams often start with theories of change that are full of both productive and misguided assumptions. Through a systematic process of testing each element, teams can ask the right questions, challenge their assumptions, and produce the kinds of insights that propel successful iteration. This highly recursive process requires systematic thinking, humility, and resilience. It also requires avoiding the trap of focusing solely on UX considerations, a mistake all too common among novice designers. In both cases highlighted here, LX considerations were paramount. From project conception to product launch, the designers explicitly defined, tested, and iterated on the learning theories embedded in their theories of change. The interplay of learners, goals, and mechanisms required a long and iterative process of theorizing, prototyping, testing, and refining, as the designers used increasingly specific indicators and measures of both learning and usability to drive their design decisions.

The TeachAids and Motion Math stories shine light on the ways that theories of change and the assumptions behind them can drive the important questions that are asked by LX designers, as well as the iterative designs and learner testing protocols that are developed to answer them. In both cases, it was through continually asking and testing these theory-driven questions that elegant and effective learning tools methodically took form. The designers clearly identified target learners, learning goals, and mechanisms from the learning sciences to develop a theory of change to test and refine over multiple iterations. As different as these tools are, they are similar in their illustration of how a well researched, thoughtfully developed, and clearly articulated theory of change drives productive LX design.

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Acknowledgements

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[1] The Apple iPhone was first released in June 2007. The first iPad was released in April 2010.

[2] Now known as "Bounce," the first game was known at the time simply as "Motion Math."

[3] Now known as "Prevention Begins With Me," the first app was known at the time simply as "TeachAIDS." The organization rebranded as "TeachAids" and has since launched an additional product line known as CrashCourse, which was developed through a methodology adapted from the Prevention Begins With Me body of work. It provides students, parents, and coaches with the latest medical information about prevention and treatment of concussions.

[4] Sorcar examined the teaching of taboo topics in other contexts as well for her doctoral dissertation. These included teaching about breast cancer in Native American communities and teaching about maternal health in Mali.

[5] Interestingly, a strong demand arose after the launch of the curriculum for a less interactive, more linear version. As the success of the intervention spread, it was requested in contexts with less access to technology and the internet. In response, the team developed a version that could be played like a movie.

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Keith Bowen is a researcher and instructor at Stanford University who works at the intersection of technology, Learning Experience Design (LX Design), and education. He has extensive experience developing and studying innovative programs that blend best practices in teaching (e.g., collaborative learning, cross-cultural learning, and problem-based learning) with emerging technologies that are both scalable and sustainable (e.g., online platforms, digital cinema, multiplayer simulation, and virtual reality). He is currently studying the design and impact of educational technology programs that connect students in high-income and low-income countries, with special focus on fragile states and zones of conflict. Working with faculty partners at Stanford, as well as other universities in the US, UK, Australia, Lebanon, and Pakistan, he has designed, developed, and studied a series of Virtual Student Exchange courses in the fields of global health, international education, and international journalism. These programs have resulted in higher student engagement, reduction in stereotypes about the other, improvement in attitudes towards the other, building of relationships across cultures, and development of professional capacity in global environments. To these efforts, Bowen brings over 10 years of experiences training practitioners in Eastern Europe, the Balkans, South Africa, Rwanda, Sudan, Nepal, Iraq, Afghanistan, and Pakistan, as well as teaching students in the U.S. and other Western countries who aspire to work overseas in government, non-profits, education, and the private sector. He has developed educational programs that have been completed by tens of thousands of learners, and he has had several educational documentaries distributed by the Discovery Channel.

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Flow Theory and Learning Experience Design in Gamified Learning Environments

Scott W. Vann & Andrew A. Tawfik

Gamification   Human-computer Interaction   Learning Experience Design   Flow Theory   Game-based Learning

Design Case

Learning technologies should be designed in a way that facilitates student knowledge construction. While much of the learning technology literature often focuses on retention of content, less is known about the theories and models that influence how learners perceive and react to the interface. In this chapter, we describe the theoretical tenets of flow theory and its application for learning experience design, especially for gamified learning environments. We then present a design case that details how flow theory was applied towards the redesign of an online professional development course. Implications for theory and practice are also discussed.

1. Introduction

To date, various theories and models describe effective ways to implement learning technologies within classroom settings (Tosuntaş et al., 2015). Other theories and models describe how to best design interfaces in ways that supports constructivist principles, including self-directed learning (Ge et al., 2016; Loyens et al., 2008), scaffolding strategies (Kim et al., 2017), and collaborative learning approaches (Chen et al., 2018). Indeed, the empirical studies based on these theories or models underscore the importance of learning principles in supporting student success.

While much of the learning technology research is often focused on the student outcomes, less emphasis has been placed on the role of learning experience design (LXD). That is, how the interface design aligns with principles of human-computer interaction and learning processes to support student knowledge construction. As such, designers that approach the interface from only a learning theory perspective may encounter unforeseen obstacles due to user experience (UX) challenges. For example, a design might technically apply soft scaffolding but fail to do so in a way that is conducive for fluid navigation. Similarly, an interface could apply the First Principles of Instruction (Merrill, 2018) but overlook the role of aesthetics and error prevention during the design process. While learning theory provides the foundation for how one constructs knowledge and engages in meaning-making, an equally important part is how the interface design mediates that process for the learner. A failure to consider both equally is disruptive to knowledge construction and thus renders the technology ineffective for meaningful learning.

This chapter argues that flow theory is an approach that equally describes the learning process and user-experience. Flow theory describes the state of flow in which learners are so engrossed in an activity that they lose sense of time

and no other activity matters during that time. While in this mental state of flow, self-consciousness can fade and the sense of time can become distorted (Csikszentmihalyi, 1991). During this state of flow, learners' engagement is often high and they have intense concentration on the task. Moreover, the theory includes cognitive elements, such as feedback immediacy and focused attention, in addition to affective constructs (engagement, self-rewarding experience). In doing so, the theory describes the cognitive processes that influence learning, while also providing a purview to understand the human-computer interaction elements of interface design.

To better understand LXD, this chapter will describe the theoretical foundations of flow theory (Guo et al., 2016) and its implications for interface design. In terms of the latter, the chapter will detail a design case (Boling, 2010) about how the engagement construct within flow theory was applied towards LXD in a gamified learning environment.

2. Flow Theory

One of the principal theories associated with engagement and gamification is flow theory, also known as optimal experience theory (Guo et al., 2016). Csikszentmihalyi's (1975) research sought to understand how performers expend considerable energy and time on their activities. His research coined the term flow experience whereby concentration, interest, and enjoyment are experienced simultaneously (Csikszentmihalyi, 1997). The theory further argues that three channels exist for learning: boredom channel, flow channel, and frustration channel (Sharek & Wiebe, 2011). As a learner proceeds through a task, one's flow state is likely to be preserved if the task difficulty increases to match the developing skills. Furthermore, the "boredom area" will result if the challenge fails to increase as the learner's skills and ability develops. In the boredom channel, the individual is not interested in the task and quickly disengages from the activity. Alternatively, an individual can fall into the frustration area if their skill/ability level is not comparable to the difficulty inherent within the task. The tasks within the frustration channel may be of interest to her or him, but the task becomes so challenging that they lose motivation to persist. The goal is for the activity to fall between these channels so that interest and challenge is maintained over time (Csikszentmihalyi, 1991).
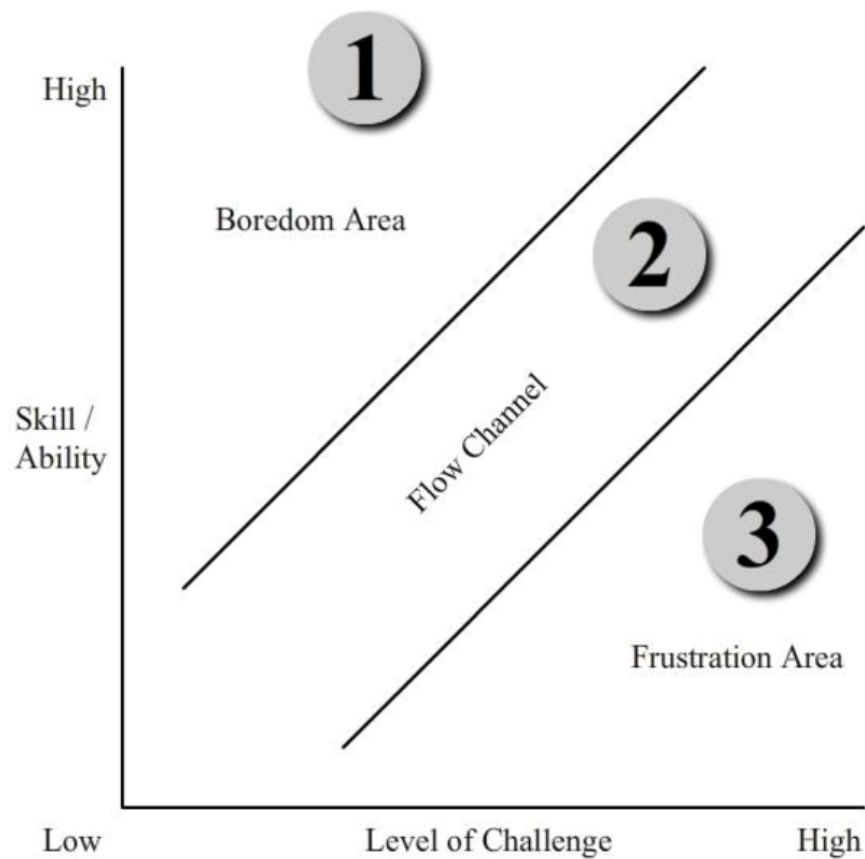
Figure 1

Three Conditions Based on Flow Theory

Note. Adapted from Csikszentmihalyi (1990).

In many cases, learners begin a new task with a knowledge gap and low set of skills; therefore, their task should correspond with an appropriate level of challenge in order to maintain within the flow channel. Csikszentmihalyi (1990) further argues:

"... when culture succeeds in evolving a set of goals and rules so compelling and so well matched to the skills of the population that its members are able to experience flow with unusual frequency and intensity, the analogy between games and cultures is even closer. In such a case we can say that the culture as a whole becomes a 'great game' " (Csikszentmihalyi, 1990, p. 81).

While in this mental state of flow, an individual's self-consciousness is minimized and perceptions of time are distorted (Csikszentmihalyi, 1997). It is during this state of flow that their engagement is high, and they have an intense concentration on the task.

2.1. Dimensions of Flow in Learning Experience Design (LXD)

As the theory evolved, Csikszentmihalyi (1991, 1997) defined the following eight dimensions of flow to define optimal flow performance:

- Clear goals and immediate feedback
- Equilibrium between the level of challenge and personal skill
- Sense of potential control
- Merging of action and awareness
- Focused concentration
- Loss of self-consciousness
- Self-rewarding experience

The first construct of flow theory includes clear goals and immediate feedback. The implementation of this construct through learning experience design allows the learner to know what is expected of them and receive instantaneous assessment on their performance. The sense of anticipation resulting from feedback is an important aspect of sustaining flow. Clear goals and feedback immediacy is balanced with the second construct: equilibrium between the level of challenge and personal skills. The experience should be designed in a balanced way where the challenge is comparable to the skillset of the learner. If the challenge is too demanding, the learner can get frustrated or easily bored with the task. In terms of interface design, the user should feel engaged by the task but not overwhelmed by the design or learning requirements. The next construct necessitates the design include a sense of potential control that engenders investment with the task at hand and thus makes the activity relevant to the learner. Collectively, these constructs describe elements of learner control and engagement.

The above elements of flow set the stage for an altered state that sustains the flow experience. The fourth requirement of flow design includes merging of action and awareness. In order for a learner to experience flow, they should be completely absorbed in the task at hand. In terms of LXD, interface designs that do not facilitate fluidity in learning are likely to disrupt flow. The previous construct mirrors the next construct of focused concentration; that is, being locked into a task creates an optimal environment for flow to occur. By experiencing high levels of increased concentration, learners become absorbed in the activity and enter into a state of flow. The interface should thus balance design features that allows a user to progress in their learning journey, while also limiting distracting information that may preclude sustained attention. Over time, the design helps learners to engage in a loss of self-consciousness whereby they becomes so immersed in the task they lose awareness of their surroundings. Moreover, flow experience design is also characterized by time distortion due to the high levels of concentration. The flow experience is therefore perceived as a self-rewarding experience. If the goals are clearly defined and obtainable by the learner, the task becomes autotelic and an intrinsically rewarding activity.

2.2. Learning Experience Design and Flow Theory in Game-Based Learning

According to the literature, researchers argue that individuals participate in an activity with a fuller sense of self-initiation if they find the activity to be interesting and engaging (Choi et al., 2007; Guo et al., 2016; Holyoke & Larson, 2009). To better leverage this affective component, research studies have sought to explore the degree to which gamification can improve learning outcomes within higher education (Breuer & Bente, 2010; Hanus & Fox, 2015; Rawendy et al., 2017). Indeed, one of the core purposes of gamification is to use design principles from games to make learning a more positive and enjoyable experience (Baxter et al., 2015). In line with gamified approaches, flow begins with recognizing and expounding one's goals and creating actionable objectives to attain those goals (Antonaci et al., 2018; Liu et al., 2017). For example, a well-developed game supports flow because it affords a challenging, goal-oriented activity as one moves towards an attainable, objective goal (Moneta & Csikszentmihalyi, 1996). Games also provide the individual with autonomy and control over the learning experience. Research has shown a direct link between increased levels of engagement and the introduction of gamification elements to learners in online courses (Buckley & Doyle, 2016; Hanus & Fox, 2015).

3. Design Case of Flow Theory and LXD

As noted earlier, the theoretical tenets of flow theory align well with gamified approaches to learning. In the section that follows, we detail a design case that describes how the principles of flow theory were applied towards the gamification of a professional development course. The following design case describes the constraints, tensions, and decisions as part of the overall design experience of the artifact (Boling, 2010). Specifically, we describe how features such as leaderboard, adaptive release, and other tools facilitated states of flow especially as it relates to engagement.

3.1. Stakeholders

Studies show that higher education institutions continue to expand their online programs to meet student demand for distance courses (Brinkley-Etzkorn, 2018). Online education in a web-based format is thus the fastest-growing segment of higher education in the United States; two-thirds of higher educational institutions offer courses using this approach (Bozkurt et al., 2015). In response, faculty are now encouraged to design and migrate their courses to digital formats. This creates a need for professional development defined as organized opportunities designed to enhance faculty practice (Belland et al., 2015; Nathan & Petrosino, 2003). Professional development is especially important for online faculty because it allows them to work together, share ideas, and reflect on various teaching strategies using the new technology (Zygouris-Coe & Swan, 2010). Indeed, there is a vast amount of literature on the importance of providing adequate professional development to faculty so they are properly prepared to teach online (Elliott et al., 2015; Weschke & Canipe, 2010; Wingo et al., 2017). For these reasons, faculty continue to engage in professional development to align their instruction with the shifting educational landscape. At the same time, trainers are needed to provide professional development in a way that is engaging and effective for faculty.

3.2. Context

The design case took place at a southeastern urban research university with approximately 23,000 students and 1,400 faculty within 13 colleges and schools. The university offers over 250 areas of study and over 120 different degree programs. The university is accredited by the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC). The university offers over 70 different fully online programs, many which are nationally ranked in their disciplines. In line with prior studies (Brinkley-Etzkorn, 2018; Elliott et al., 2015; Herman, 2012), faculty members at this institution commented on being dissatisfied with the current professional development opportunities for online instruction within the institution. In this design case, many of the university' PD opportunities were not on-demand, seen as irrelevant to the targeted audience, and perceived as boring.

As a researcher and a practicing instructional designer, the first author is often faced with the challenge to foster engagement in professional development within higher education contexts. The researcher believed that flow theory and related empirical evidence supported the idea that gamification can be used to engage faculty in professional development opportunities. Additionally, the first author believed this information would provide great value not only to researchers and instructional designers, but also to the institution's professional development initiatives. Specifically, faculty could develop their own engaging course content and instructional strategies that could directly impact student success.

3.3. Course Description

The institution originally offered traditional face-to-face professional development sessions. However, the traditional face-to-face onboarding was poorly attended and failed to support faculty working remotely. Eventually, due to the sizable growth of new online programs at the university and increase of educators operating remotely, the institution decided all faculty onboarding would be conducted online. As digital learning options increased, the institution leveraged an initiative called the Universal Design for Learning (UDL) to support teachers as they design classes for all learners. The UDL content was therefore digitized and incorporated within the university's LMS into an asynchronous, self-paced professional development course for online instructors. As we will describe later, the UDL's online, professional development course was specifically redesigned using elements of flow theory and gamification.

Figure 2

Welcome Page From the Gamified PD Course of Universal Design for Learning

The course had the following organization. After watching an online video orientation on how to navigate the professional development course, faculty were given access to the materials by the Center for Innovative Teaching and Learning (Figure 2). The introduction video to the professional development also explained the various gamification elements added to the course (badging, leaderboards, content leveling, etc.) and how they are applied to the learning objectives. The course, titled "Reaching All Learners," consists of four instructional modules: (a) Introduction to Universal Design for Learning, (b) Engagement – The Why of Learning, (c) Representation – The What of Learning, and (d) Action & Expression – The How of Learning. The course corresponded with the following learning goals:

- A working knowledge of the theory and research basis of UDL that includes how individual variability plays out in different educational environments.
- Strategies for evaluating and improving lessons to reach more varied learners and to support high levels of engagement and achievement for all learners.
- Tips, guidelines, and techniques for applying UDL principles to the design of lessons and curriculum units that need to be aligned to educational standards.
- Strategies for using new technologies, to make the curriculum more effective.

Each instructional module was self-paced and took participants an estimated 10-15 minutes to complete. Participants were presented with the research basis for UDL, practical applications of UDL to lesson design, and helpful technology tools that support flexible, inclusive instruction. Additionally, the course provided online faculty with practical strategies and techniques to ensure that all online courses at the university met the high expectations of online learning at the institution. Before starting the first instructional unit, learners were also presented with a pre-knowledge check that assessed their prior knowledge of UDL principles within the "Getting Started" module. This pre-assessment pulled questions from various knowledge checks within the course. At the end of each module, a comprehensive knowledge

check of that module was provided using multiple choice questions. The assessments were designed with unlimited attempts, but learners could advance to the next module only after scoring an 80% or higher.

3.4. Rationale for Flow Theory

The professional development's design sought to increase faculty's engagement using gamification elements and flow theory within the course to improve faculty's understanding of UDL. The design choice was based on prior studies that show gamification increases learners' engagement within various online settings (Brigham, 2015; Buckley & Doyle, 2016; Kuo & Chuang, 2016; Mekler et al., 2017). The portion of the research on gamification-based learning is specifically grounded in the theoretical framework of flow theory, which includes the principle of learner engagement (Csikszentmihalyi, 2014; Dicheva et al., 2015; Kuo & Chuang, 2016). In line with the literature (Landers et al., 2017), gamified elements were chosen to place the faculty member at the center of learning and promote engagement within the professional development course. By affording decision making opportunities and creating challenges throughout the course, the learner adopted more ownership of their knowledge construction.

3.5. Course Design Using Flow Theory and Gamified Learning

Multiple design elements were included to support flow theory and gamified learning. As participants progressed within the online professional development (PD) course, instant feedback mechanisms were used in the course to maintain their flow. Once a participant completed a knowledge check, they were immediately provided the results and feedback on the questions that were missed. The missed questions provided information on where participants could locate relevant content within the course. Successfully completing the knowledge check in the module awarded the participant the badge for the associated UDL competency. Badges were displayed as icons and served as a visual representation when mastery had been achieved on a particular concept. Additionally, the participant was also awarded points for each badge obtained and associated point values were added to the course leaderboard. Once a participant successfully obtained all the badges within the instructional module, a certificate of completion was automatically generated and awarded to the participant.

The design of the online PD used additional gamification elements (badging, leaderboard, content leveling, and certificate of completion) to promote engagement and create an optimal learning environment for a flow state to occur. Each instructional module had an associated badge based on a set amount of points that could be earned once the module was successfully completed (Figure 3). By incorporating attainable goals through badging, this feedback provided the learners with short term sustained engagement (Brigham, 2015; Hamari, 2017). Related literature explains how badges might further drive motivation in the short term by presenting learners with specific tasks which unlock extrinsic awards (Kyewski & Krämer, 2018). Therefore, the badges were micro-learning goals that allowed the learners to perceive a sense of achievement and progression as they were awarded for completed modules. By being presented with smaller challenges, the badges design supported short term concentration on tasks and thus supported flow.

Figure 3

The Badges Available to a Participant Within the Universal Design for Learning Gamified Online PD

A leaderboard was also applied to the course and displayed as a widget on the homepage, which informed each participant how their colleagues performed within the class. Each badge earned within the course and certificate awarded at the end contained a set point value. After a badge was awarded to the participant, the leaderboard was updated to reflect the points obtained. The leaderboard was used to examine the relationship of gamification's competitive aspect to increased flow and engagement within the PD course. According to the literature, leaderboards have had varied results on increasing engagement in online learning (Kuo & Chuang, 2016; Özhan & Kocadere, 2020). Throughout the PD, some learners checked the leaderboard routinely to compare their score against their peers. The leaderboard thus provided increased engagement by allowing learners to compare their achievements with their peers in a communal setting. The focus on obtaining points to increase their communal ranking on the leaderboards produced competition that may have renewed interest in completing tasks, increased engagement, and therefore prevented learners from drifting into the boredom channel. Our research study may have vindicated previous research results showing that a sense of self-reward and task-based challenges provide an optimal state for flow to occur (Csikszentmihalyi, 1991, 2014).

To avoid the frustration channel, content leveling was also included to segment the PD (Mayer & Moreno, 2003; Su, 2016). Content leveling was achieved by applying release conditions to the modules, which were linked to learning competencies within the PD. For example, the module on "Representation: The What of Learning" would not be unlocked until the competency was completed for "Engagement: The Way Learning" (Figure 4). As noted earlier, a competency is achieved by scoring an 80% or better on the knowledge check assessment within the module. The PD was purposely designed with segmentation in mind, allowing for the learner to stay within the optimal channel of flow and releasing content at the ideal time. By providing content leveling through segmentation, the participant could avoid the boredom channel by not having to wait on additional content to be released. Furthermore, the participants were provided with a clear sense of progression and earned points by "leveling up" with the release of the corresponding

badge and next module of content. By providing clear goals and immediate feedback on level completion, the design was able to facilitate and sustain flow for the user.

Figure 4

An Example of a Release Condition Linked to the Achievement of a Competency

As participants progressed within the PD, instant feedback mechanisms were used in the course. Once a participant completed a knowledge check, they were immediately provided the results, along with information on the questions that were missed. The missed questions provided information on where participants could revisit the content within the course. Knowledge checks were configured for unlimited attempts and participants passed the assessment only after they scored an 80% or better. Additionally, the participant was also awarded points for each badge obtained and the point values were added to the course leaderboard. This allowed for the learner to be certain of the decision-making, progressing at their own rate. Successfully completing the knowledge check in the module awarded the participant the corresponding badge for the corresponding UDL competency.

Once a participant successfully obtained all the badges within the course, a certificate of completion was automatically generated and awarded to the participant. The certificate was customized to the participant and contained their full name, along with the university logo and signature from the Director of Distance Learning (Figure 5). The LMS provided the ability to add replace strings on the award certificate, which allowed for the automation of the award information (ex. name, date, issuing department, and the name of the PD). In addition to badges, summative certificates serve as an additional external motivator and catalyst for flow to occur. That said, the certificate differed from badges in terms of perceived rigor and length of concentration required for obtaining the award. While the badges were a reward for short-term, individual achievement, the participants found the certificate was the primary external motivation for completing the PD because they could be shared with their peers (i.e., department chair, colleagues). In doing so, the PD interface design suggests the different external motivators could have attributed to a sustained state of flow by providing a longer concentration on task and presenting a greater challenge for this macro-learning artifact.

Figure 5

An Example of a Certificate of Completion That Was Generated for a Participant Within the Online PD Course of Universal Design for Learning

3.6. Lessons Learned and Implications

The focus of this case study was online faculty's perceptions of engagement within a gamified professional development course. The results of the study suggest that online faculty PD is not a uniform approach. While the literature has described PD characteristically lacking engagement, using flow theory to design the course may be one way to offset this flaw in the PD's potential learning experience. Furthermore, the design case also suggests that providing participants with a challenge not only drives engagement, but also can provide a sense of reward and accomplishment by completing the challenge. By providing challenges in a way that aligns with flow theory, participants can experience increased engagement to complete the required tasks to further progress within the PD.

Additionally, PD design should be centered around a gamified design that provides participants not only with intrinsic motivation, but also extrinsic motivation to stay engaged. The results of this study showed how badges provided participants with an instant reward for obtaining a learning goal, drove the participant to obtain all the badges, and consequently sustained flow within the PD. The didactic offerings of PD traditionally do not provide participants with extrinsic motivation (e.g., awards) to stay engaged. That said, instructional designers should keep in mind that the awards should be implemented in a way that brings value and are applicable to the participant. In terms of game competition, the design case describes how competition drove engagement and created an optimal environment for flow to occur. The design case thus suggests that competition is not only a community driven idea, but can also be done on an individual basis within the gamified learning environment. As stated previously in literature review, studies have shown the positive effect that competitive gamification features, such as a leaderboard, has on engagement as participants interact on tasks to increase social ranking. However, the results of the study suggest participants were also motivated to obtain all the available awards for personal accomplishment and not solely for community

recognition. The final suggestion to sustain flow regards segmentation of the content. The results of the current study suggest that segmentation can lead to an optimal flow state of concentration and intense focus. As stated earlier, if the PD is not instructor driven, the design should be centered around self-directed learning. However, for self-directed learning to be effective, design strategies should take cognitive load into account. These design strategies include checkpoints for progression of content, clearly identifying the PD learning goals, and using consistent organization of the modules. The results of the study show that gamification can assist with segmentation by using content leveling tactics to release content based on a set of required conditions. By creating PD around segmentation design, participants could experience increased engagement, maintain cognitive load and have a clear path of completion.

4. Limitations

Although the design case highlights how flow theory could be applied to a gamified approach, there are opportunities for other designers implementing LXD. The design case was limited to the gamification features of badging, award certificate, content leveling, and a leaderboard due to the limitations of the selected LMS. Ideally, the design would have examined additional gamification features not afforded by the LMS. For example, the design could have benefited from additional gamification elements such as digital avatars, a progress bar within the content modules, and actual games within the PD course. By including additional gamification features in the design, a more holistic understanding of engagement and flow could be gained from these different elements. Future design cases could also examine flow perceptions over time from a longitudinal perspective, instead of the short amount of time that learners were engaged with this course.

5. Conclusion

Researchers argue the application of theory towards interface design is an important element in how learning is supported (da Rocha Seixas et al., 2016; Hwang et al., 2012). We argue the elements of effective LXD have yet to be addressed within many approaches to learning systems design. To better address the intersection of learning theory and human-computer interaction, Csikszentmihalyi (1991) provides the following eight dimensions of optimal flow performance to increase user engagement: clear goals and immediate feedback, equilibrium between the level of challenge and personal skill, merging of action and awareness, focused concentration, sense of potential control, loss of self-consciousness, time distortion, tutotelic or self-rewarding experience. As it relates to learning experience design, interfaces should be designed to experience the flow channel using the above constructs. For example, a well-developed LXD often causes individuals to experience flow through a challenging activity that requires skill and has an attainable, objective goal (Moneta & Csikszentmihalyi, 1996). Alternatively, flow theory highlights how a poorly designed interface can preclude meaningful learning; that is, interface design can disrupt learners attainment of flow status and lead towards the boredom or frustration channel.

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Color Theory in Experience Design

Royce Kimmons

Color   Visual Design   Aesthetics   Emotion

Choosing colors is an essential component of UX and LX design that is often either overlooked in design coursework and research or that is approached in a non-scientific manner. Yet, colors elicit various emotional and physiological reactions from users that are important for designers to understand, and these reactions are determined by various factors associated with the colors themselves (e.g., hue, saturation, brightness) as well as the cultural and experiential backgrounds of users (e.g., this color reminds me of X). This chapter explains essential knowledge about how color technically works, summarizes what research has shown about how color choice relates to emotions and learning, and provides guidelines for designers to follow in order to more effectively incorporate color into their designs. I then conclude by providing guidance on how to intentionally develop and use different types of color schemes to better achieve design goals and to improve user experiences.

1. Introduction

Outside the visual arts, color is rarely discussed by professionals in systematic ways; among UX and LX designers, color is generally approached in a strange give-and-take between technical prescription and intuitive preference. For instance, the color system outlined in Google's (n.d.) material design visual language provides precise guidance on how to generate a color palette from your primary color, what to use secondary colors for, and what colors are typical for specific elements (such as error screens), but it does not provide designers any guidance on what primary color to pick in the first place, when to use different types of color palettes (e.g., analogous, complementary, triadic), and why. This is likely because, when designing for a corporate client, designers are generally constrained by the preexisting branding requirements of the client (e.g., "our brand is periwinkle") and must work from a particular color starting point when making designs.

But designers must also often counterbalance their own and their clients' everyday assumptions and receive wisdom about color in order to create the best designs for end users and learners. For instance, early in my professional experience creating websites for clients, I delivered a mock-up that I thought looked good and met the client's requests perfectly. Frustrated with what he saw, the client furrowed his brow and slowly replied, "Yes, but I need something that pops." This, in turn, frustrated me, because the only explanation he then provided would result in what I thought would be a terrible-looking design. "What does 'pop' really mean?" I thought. And "How can I fix the design to be something that the client likes and something that I'm proud of?" And, perhaps most of all, "How can my client and I communicate about color in more meaningful ways?"

Beyond this need for designers to meaningfully communicate with clients, color also plays an important affective and cognitive role in learners' experiences. Various studies have shown that color-use influences learner attitudes, comprehension, and retention (Gaines & Curry, 2011). Some of these influences are broadly universalizable, others are contextual to the learner's age, gender, or culture, and others are contextual to the subject matter or learning objectives being targeted. Furthermore, there might be multiple right or useful ways to use color in a particular design project, and inappropriate or ineffective color-use in one project might constitute optimal use in another.

For these reasons, clear and reliable guidance on the what, how, when, and why of color-use in UX design is difficult to come by, and the problem of effective color-use is a prime example of why UX design cannot be approached purely as a science nor as an art but as a craft that synergistically merges the two. Toward this end, I will begin in this chapter by briefly providing some rudimentary groundwork on the underlying physics of color and its technical representation in digital formats. This will give us a common vocabulary for referencing specific aspects of color (e.g., hue vs. tone) as well as some technical knowledge necessary for actually using color in UX design scenarios. After this, I will briefly explore the science of color-use in UX by summarizing some of the emotional, cognitive, and physiological effects that color-use has on learners.

With this backdrop, I will then address some of the applied aspects of color-use that will influence the craft of UX and ongoing research in this area. Specifically, I will explore four guiding considerations of color-use that should be addressed in UX — contrast, attention, meaning, and harmony—and then provide guidance on how to use color schemes to improve harmony by highlighting five dominant types of color schemes. I will then conclude by providing specific craft guidance on using color for UX projects and comment on how this should connect to ongoing UX research.

2. Physics of Color and Technical Use

We must begin this chapter by reviewing some of the physics of light and color. Color is a visual sensation created in the mind of the viewer from differing wavelengths of visible light, ranging from low-frequency reds to high-frequency violets. Some color sensations can be produced by a narrow band of wavelengths, but others are produced as multiple color wavelengths are mixed. For instance, when all color wavelengths are mixed together, they make white light, which is why a dispersive prism can be used to split white light into a rainbow of spectral colors. By putting the primary colors of light together, then, white can be created additively, as in Figure 1, and various other colors not even present in the rainbow can be created by mixing light wavelengths together, such as red and blue making magenta.
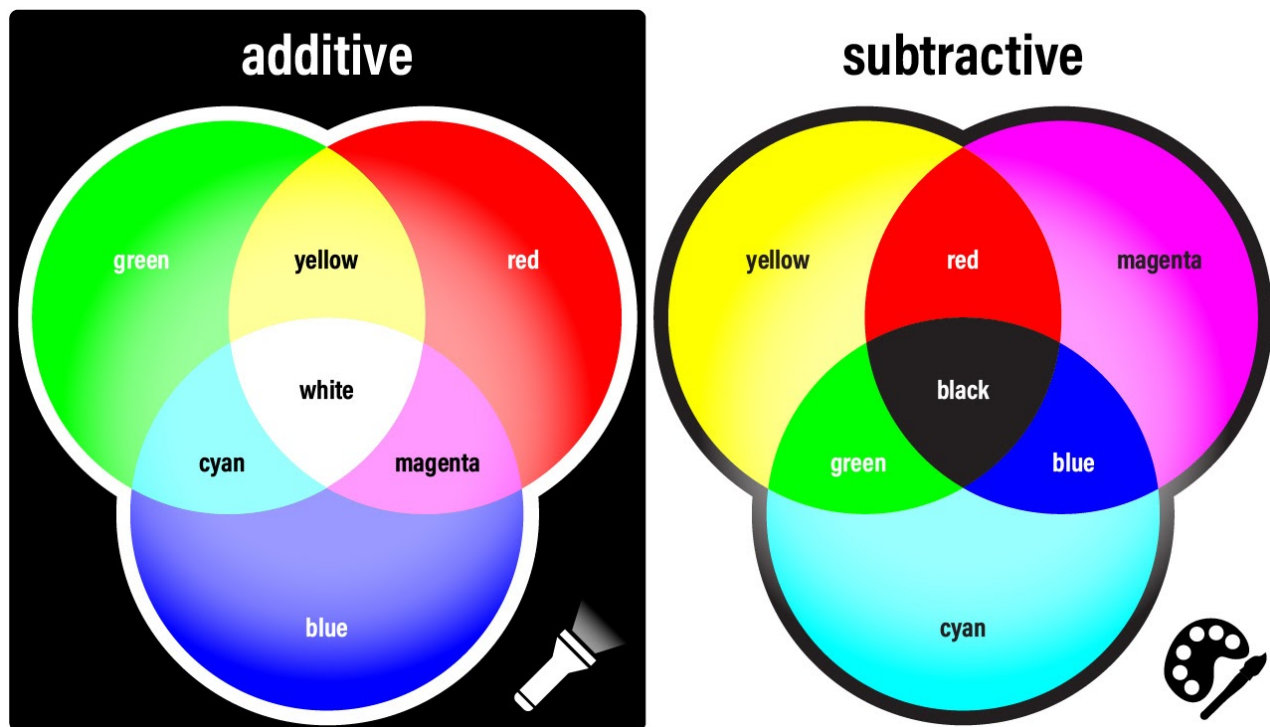
Figure 1

Additive and Subtractive Color Mixing Models

For this reason, computer screens and other displays have historically used differing intensities of only three primary colors of light: red, green, and blue (RGB). On screens, RGB dots are used in combination to create colors ranging from white, when they are at full intensity, to black, when they produce no light, and the millions of color combinations in between that are commonly used in movies, games, simulations, images, and websites.

However, visual media that rely upon physical materials to reflect (rather than generate) light, such as ink and paint, operate from a different model of color mixing. Though mixing a green ray of light and a red ray of light would produce yellow light, combining green paint and red paint would produce a dark brown. Such materials rely upon a subtractive color model (cf. Figure 1), wherein black is the sum of all colors and white is the absence of all colors.

Recognizing these two approaches to color mixing is important to understand common notations present in design and authoring software. For instance, when creating a website, video game, mobile app, or illustration, RGB notations are used, such as rgb(255,255,0) for yellow, wherein each number represents a range of 0 (lowest) to 255 (highest) intensity for the primary colors. Hexadecimal notations are also commonly used as a shorthand version of RGB, such as #ffff00, wherein the number ranges are converted to a base-16 number system, ranging from 0 to ff, without losing any information. When creating print media, on the other hand, CMYK notation is commonly used, such as cmyk(0,0,100,0) for yellow, wherein each of the primary colors is represented as a percentage of intensity (0-100%) and black is provided as a fourth color mixin, because true black is difficult to make through mixing (in real-world applications, mixing would only generate dark browns and grays). Table 1 provides some notation examples of common colors.

Table 1

Notation Examples of Common Colors

Name	Additive	Subtractive

	RGB	Hexadecimal	CMYK
White	rgb(255,255,255)	#ffffff	cmyk(0,0,0,0)
Black	rgb(0,0,0)	#000000	cmyk(0,0,0,100)
Red	rgb(255,0,0)	#ff0000	cmyk(0,100,100,0)
Green	rgb(0,255,0)	#00ff00	cmyk(100,0,100,0)
Blue	rgb(0,0,255)	#0000ff	cmyk(100,100,0,0)
Yellow	rgb(255,255,0)	#ffff00	cmyk(0,0,100,0)
Cyan	rgb(0,255,255)	#00ffff	cmyk(100,0,0,0)
Magenta	rgb(255,0,255)	#ff00ff	cmyk(0,100,0,0)
Gray	rgb(127,127,127)	#808080	cmyk(0,0,0,60)

Using any of these notations can generate millions of possible colors, including basic hues of the color wheel, low-saturation tints of hues (by lightening toward white), and low-brightness shades of hues (by darkening toward black), along with various mixtures of tinting and shading (cf. Figure 2). These terms will be important moving forward for understanding research on color effects for the affective domain. Thus, hue represents the color's position around the color wheel, saturation represents the amount of white mixed with the hue, and brightness represents the amount of black mixed with the hue.
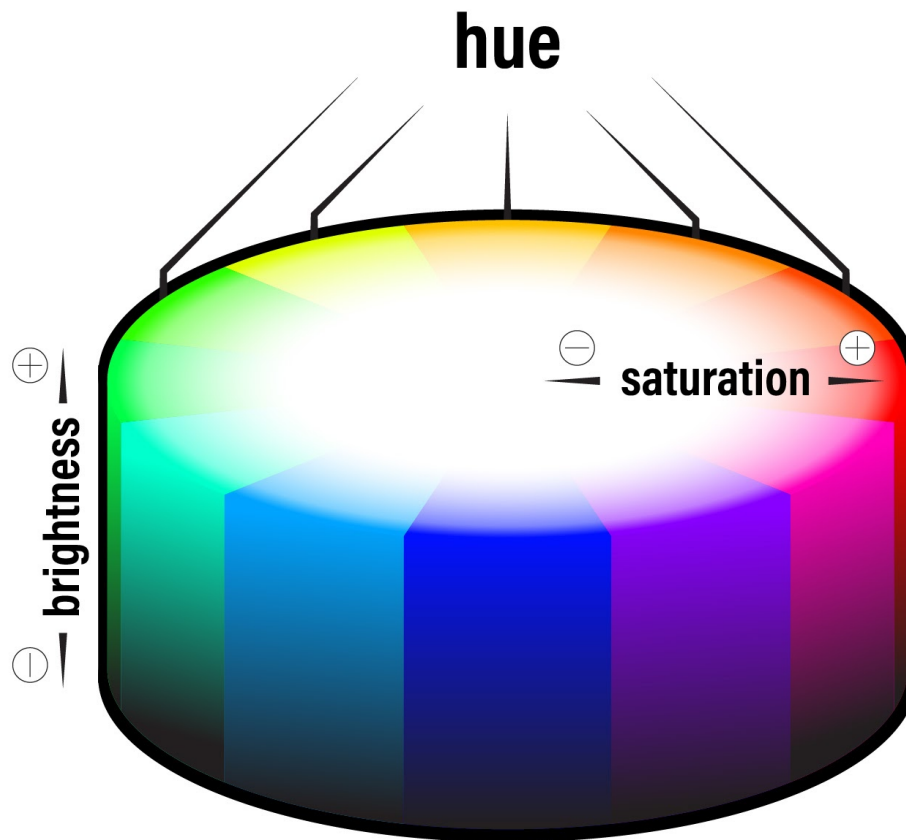
Figure 2

Hue, Saturation, and Brightness on a Color Wheel

3. Emotion and Learning

When people see the colors represented by the color wheel, they have various emotional and physiological reactions to them that influence their general experiences and also their learning. Alongside the famous cognitive domain taxonomy, Krathwohl, Bloom, and Masia (1964) also proposed a taxonomy for what they called the affective domain of learning, or the aspects of learning related to "a feeling of tone, an emotion, or a degree of acceptance or rejection" as expressed through goals oriented toward "interests, attitudes, appreciations, values, and emotional sets or biases" (p. 7). Recent years have seen renewed interest in the affective domain as educators and designers have struggled anew with how to support learner self-regulation, motivation, and persistence. Though the connection between color and learning may not be obvious at first, by influencing learner emotion, attitude, and interest, color can influence learner behaviors and attitudes, which in turn will influence their learning.

For instance, one study found that exposure to red prior to taking an IQ test subconsciously impaired performance, presumably by triggering feelings of danger, failure, or avoidance (Elliot et al., 2007). Though such emotional states might have limited direct effects on learning outcomes, they may play an important role in improving intrinsic motivation and the desire to keep working (Heidig et al., 2015); by employing positive emotion cueing, designers can help increase mental effort in the learner, reduce perceived difficulty of the material (Park et al., 2014; Um et al., 2012), and improve learner comprehension (Plass et al., 2014).

Psychological research on the emotional effects of color extends at least back to the 1950s. In their early work, Guilford and Smith (1959) found that, among the spectral colors, people preferred blue and green the most and orange and yellow the least. Subsequent research found that preference for blue, green, and white generally persisted across

countries and cultures (Adams & Osgood, 1973). Additionally, some emotional reactions are universal, such as anger, fear, and jealousy being connected to red and black, while other colors, like purple, are more culturally mediated (Hupka et al., 1997) or are influenced by gender (Osgood, 1971). For example, women take slightly more pleasure in bright colors and find highly-saturated colors slightly more psychologically arousing (Valdez & Mehrabian, 1994). Furthermore, even within a single culture, emotional reactions may change somewhat with age, such as childhood feelings of surprise and fear toward green maturing into adult feelings of happiness (e.g., Terwogt & Hoeksma, 1995).

Physiologically, studies have shown that human reactions to color vary by hue, with long-wavelength colors (e.g., reds and yellows) being more arousing (e.g., increased heart rate and respiration) than short-wavelength colors (e.g., blues and greens; Jacobs & Hustmyer, 1974; Wilson, 1966). Additionally, many studies have found that primary hues are preferred to secondary or tertiary hues (Kaya & Epps, 2004) and that all of these are preferred to grays. Some of these reactions can be explained by differences in intensity of photoreceptor stimulation in the eye (e.g., the eye is more sensitive to red), while others likely stem from common environmental experiences, such as associating white with cleanliness and blacks and grays with dirtiness (Valdez & Mehrabian, 1994).

Figure 3

Four Interface Examples That Cue Differing Behaviors, Trust Levels, Attitudes, etc.

For a simple example of how this relates to UX and LX design, consider the password prompt interfaces in Figure 3. If you were presented with each of these interfaces, how might your emotional and behavioral reaction to the prompt differ based upon its color? Seeing a red prompt might make you stop and consider "Is this really a secure site?" On the other hand, an orange prompt might get your attention but be somewhat confusing or concerning, a gray prompt might feel bland but also seem secure or professional, and a blue prompt might make you feel comfortable about entering your information when perhaps you should not be comfortable.
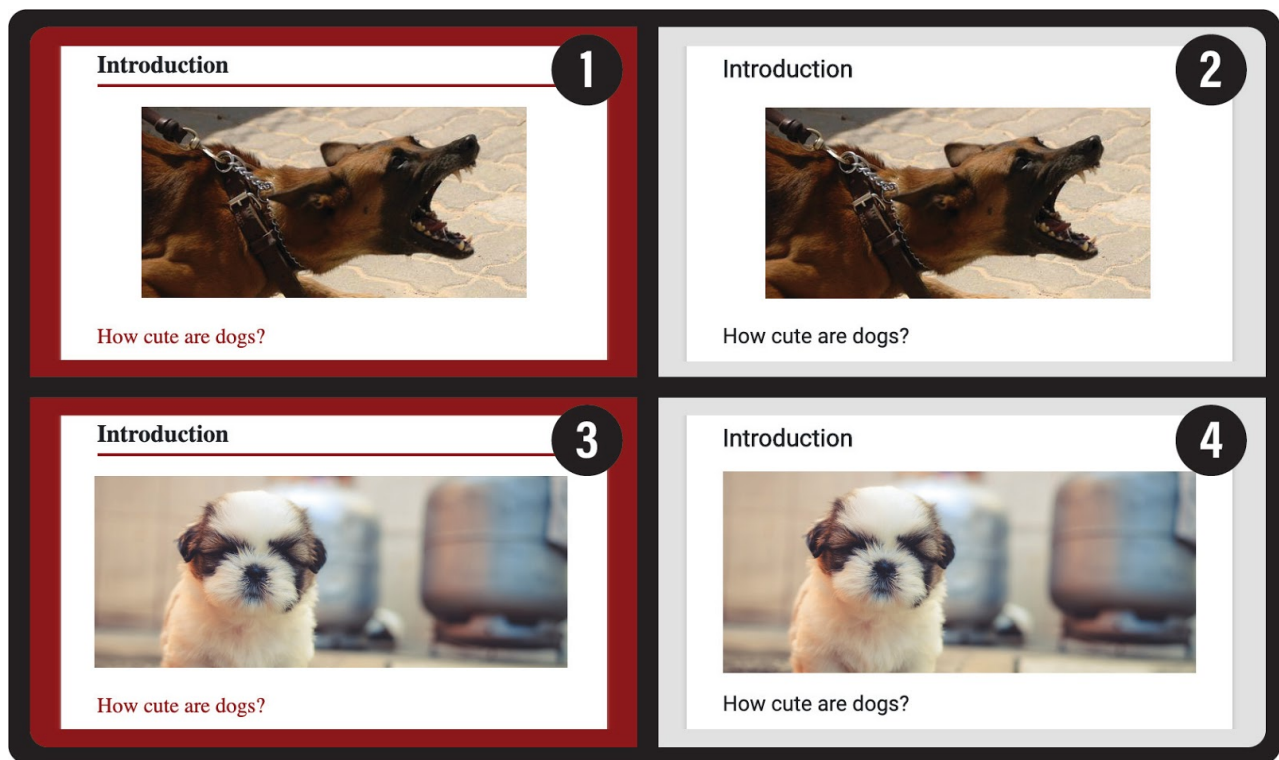
Figure 4

Four Display Options for a Mobile App About Pet Care With Variations on Color and Content

Similarly, suppose you are designing a learning app for young children on how to responsibly care for pets. In Figure 4, four options are provided. Two use an aggressive image of an adult dog (1, 2), while the other two use an image of a soft puppy (3, 4). Two also use a blood red background (1, 3), while the other two use a neutral grey (2, 4). What might be student affective reactions to each of these and how might it impact their ability to achieve learning objectives related to being a responsible pet owner? Option (1) feels very aggressive both because of the content and the color, while option (3) feels like there is a mismatch between what is shown and how it is presented, thereby evoking conflicting emotions. The neutral grey background for (2) and (4), however, allows the content to convey the emotion. And so, if our objective is for children to have a positive attitude toward pet care, then option (4) would likely be the best.
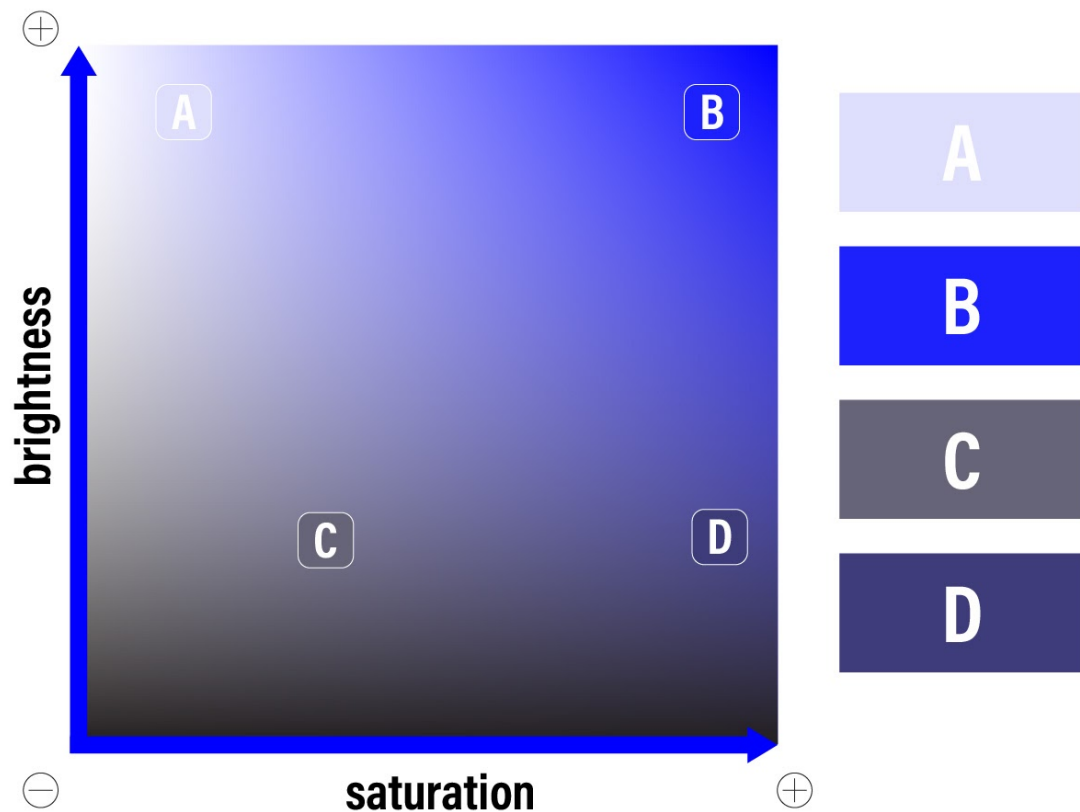
Figure 5

Brightness and Saturation Levels of the Primary Blue Hue With Four Examples

Hue is not the only aspect of color that influences emotion; a color's saturation (how little white is mixed in with it) and a color's brightness (how little black is mixed in with it) also has an effect. In research studying color effects on the Pleasure-Arousal-Dominance emotion model (Mehrabian & Russell, 1974), brightness was found to positively impact pleasure and negatively impact arousal and dominance, while saturation positively impacts all three (Valdez & Mehrabian, 1994). So, if using a blue hue, as in Figure 5, you might choose from a variety of brightness and saturation levels, including (a) light blue (high brightness, low saturation), (b) azure (high brightness, high saturation), (c) blueish gray (low brightness, low saturation), or (d) indigo (low brightness, high saturation). Though each of these is a variant of blue, they all elicit different emotional responses in the viewer. For instance, (a) would be fairly pleasurable but not arousing or dominant, eliciting a feeling of tranquility; (b) would be the most pleasurable and somewhat arousing but not dominant, eliciting a feeling of amazement or awe; (c) would be the least pleasurable and fairly neutral for arousal and dominance, eliciting a feeling of boredom; and (d) would be the most arousing and dominant but neutral-positive for pleasure, eliciting more of a feeling of boldness or antagonism (Valdez & Mehrabian, 1994). In fact, brightness and saturation account for two-thirds to three-fourths of the detected variance in users' feelings toward color (Valdez & Mehrabian, 1994). This means that shifting from soft pink to blood red in a design would likely impact users' feelings more than shifting from soft pink to soft green or blue.
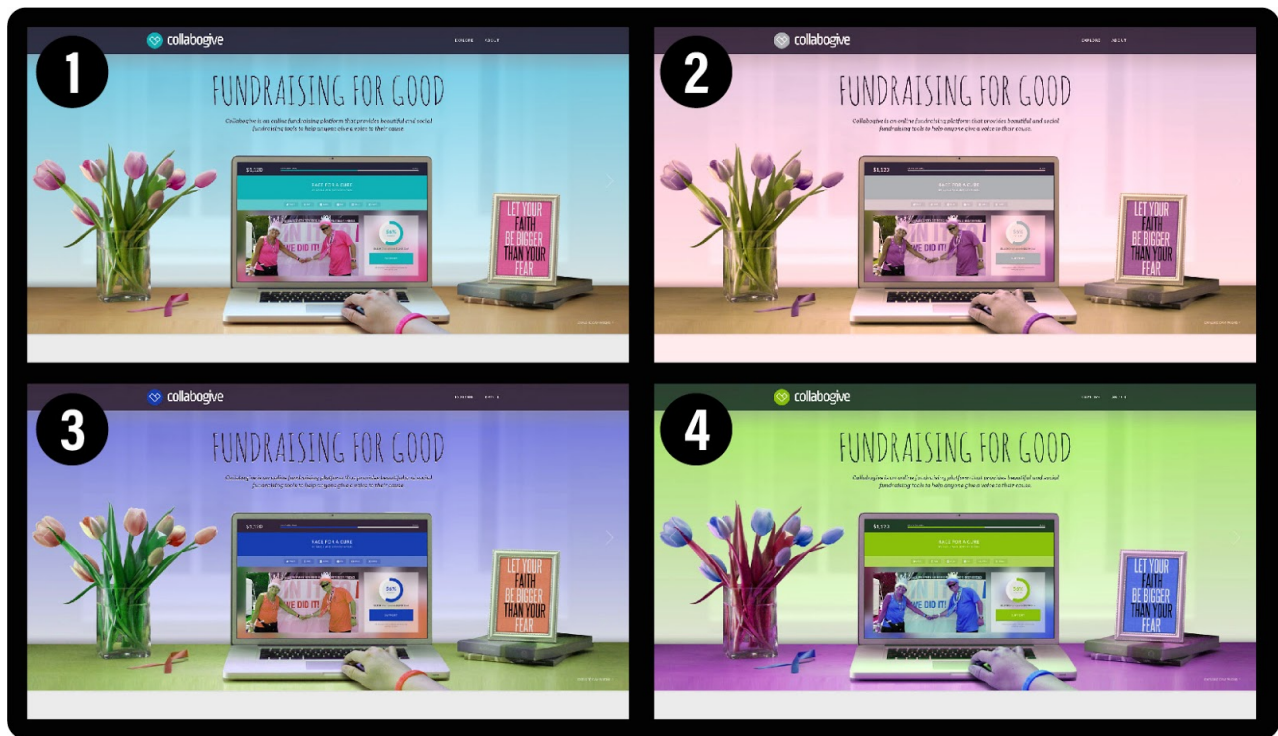
Figure 6

Four Variations of the Same Design That Elicit Different Affective Responses

In addition, the context of color-use is important, as in the case of otherwise pleasant colors being used in inappropriate or unnatural ways (Valdez & Mehrabian, 1994). Consider the four variations of the same website design in Figure 6. Which of the four color variations is your favorite? For most people, (1) would likely be the preferred variation, because not only are the colors pleasant but the color-use more appropriately aligns with prior positive experience. In the other examples, the skin color of the hand looks a bit green, which may subconsciously suggest experiences of bodily disease or death to the user; similarly, the stems of the tulips in (4) are red rather than the expected green, which signals to the user that the experience is artificial or unnatural. In such ways, whether intentionally or unintentionally, our designs evoke affective responses; just as (1) might evoke memories of beautiful blue spring days with new life, the others might conversely evoke experiences of sadness, frustration, confusion, or discomfort, all of which will influence a user's motivation and persistence with using the product.

4. Guiding Considerations

All of this research into the science of color-use is valuable, but how each of us then translates these findings into the actual, embedded craft of UX and LX design is a different matter. For this reason, a few considerations may be useful for guiding any color-use in UX and LX projects, including attending to contrast, attention, meaning, and harmony.

4.1. Contrast

First, ensuring high contrast is important in all designs for aesthetics but is especially important in those that use text. It is also a legal requirement for many UX projects to meet minimum accessibility expectations in many countries, such as those stipulated in the W3C's Web Content Accessibility Guidelines (WCAG) 2.0. Contrast problems are widespread in learning products. In fact, a recent study on K-12 school website accessibility across the U.S. found that contrast errors were the most common type of error among all sites (Kimmons & Smith, 2019). Contrast errors arise because, though two similarly-saturated colors, such as crimson and blue, may look quite different to most viewers, when superimposed (as in Figure 7) they can become difficult to decipher from one another. As a simple check of this,

colored designs can be converted to grayscale to allow you to quickly see how similar the colors are to one another, or an automated contrast checker like the one provided by WebAIM can be helpful. To solve contrast problems, white and extremely light tints should be used to contrast highly-saturated colors, and black and dark grays should be used to contrast light tints.

Figure 7

Low-Contrast and High-Contrast Examples of Analogous Color-use With Grayscale Conversions

4.2. Attention

Second, colors can be used to quickly and efficiently draw the attention of the eye to visual elements that matter. For instance, one eye-tracking study found that adding random colors to word labels on a grayscale figure moderately improved learner retention and transfer performance by improving the efficiency by which learners could differentiate textual elements (Ozcelik et al., 2009). On an app or VR interface, this might mean using a vibrant color only to effectively draw the learner's attention to a few important elements, such as commonly-used buttons or interactive elements necessary for progression. Similar principles are often applied to print media, with color only being applied to text in the case of headings, key terms, or blockquote elements. Any variation in color will generally draw the eye of the learner to the variation, and this means that UX designers should use this principle to intentionally draw user attention to elements that matter and avoid unnecessary color variation in elements that are less important. It also means that color cues can effectively be used as guideposts for directing the learner through progressive elements and to influence user pathways in desired ways.

4.3. Meaning

Third, because color conveys emotional (and sometimes even conceptual) meaning to learners, colors should be used in a manner that synergistically emphasizes the intended meaning conveyed by the overall project and individual content elements. As with the pet care mobile app example in Figure 4, improperly using color can subvert intended meaning or set a tone that is either unhelpful, dissonant, or repulsive for learners. As mentioned early, actual meaning and affective influences of color can be complicated, contextual, and individual, but some influences are fairly universal, such as grays denoting lack of importance; warm colors evoking passion, dissent, or engagement; cool colors evoking comfort, closeness, or agreement; and so forth.

4.4. Harmony

And fourth, to use colors well in any design effort, the designer must not only understand the emotions elicited by each color itself but also understand how to use colors together in harmonious ways that meet the intended purposes of the project. For instance, it is common knowledge that warm (low-wavelength) colors draw more attention than cool (high-wavelength) colors and that highly saturated colors draw more attention than washed-out tints, but the mark of a skilled designer is knowing both (a) which colors to use and (b) how to use varieties of colors together in harmonious and intentional ways.
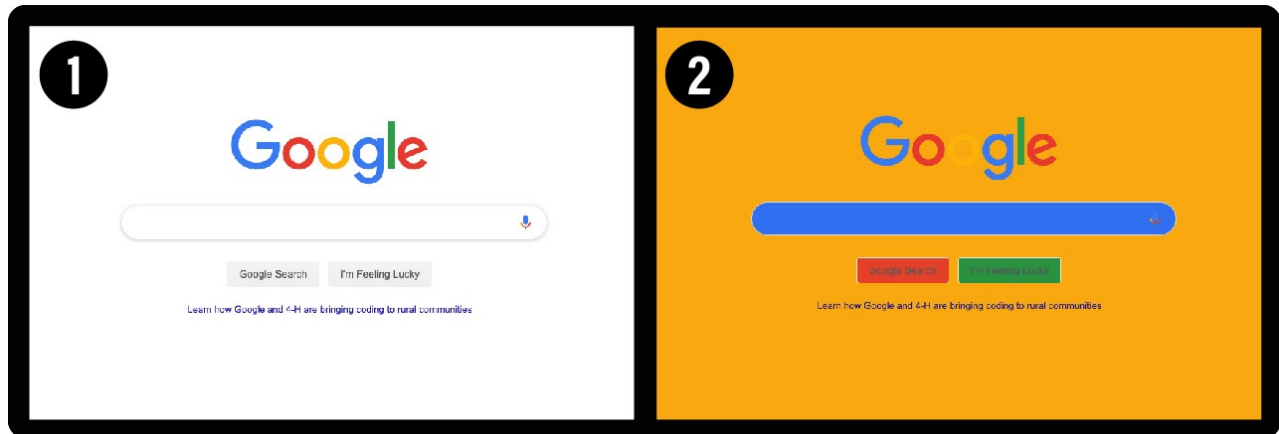

Figure 8

Two Websites Using the Same Colors but in Different Ways

Even when two products use the exact same colors (as in Figure 8), how the colors are used in relation to one another will influence the learner's affective experience. So, though both 8.1 and 8.2 use the same colors, 8.1 might feel cool, inviting, and professional, while 8.2 might feel comical, distracting, and amateurish.

As a rule of thumb, many designers propose following what is called the 60-30-10 rule, which is commonly used in many other visual fields such as interior design. According to this rule, you should choose a primary color to dominate 60% of the field of view, followed by a secondary color for 30%, and an accent or tertiary color for no more than 10%. For most UX products, this would mean choosing a subdued color as the primary color (such as the soft blue in Figure 6.1 or the white in 8.1), a vibrant color as the accent color (such as the pink in Figure 6.1 or the "Google" primary colors in 8.1), and some variation in between as the secondary color (such as the brown in Figure 6.1 or the grays in 8.1).

5. Color Schemes

To promote color harmony, and to implement the other guiding considerations mentioned above, most designers will begin color-use in a project by developing what is called a color scheme. In most cases, color schemes include between two and six colors that will be drawn upon in intentional ways. Common color scheme types include: (a) monochromatic, (b) analogous, (c) complementary, (d) complex, and (e) achromatic. Each type has its own strengths and weaknesses as well as design considerations to attend to, which I will now explain. For each type, an example image will also be provided, which has the five scheme colors depicted on the right of the image and the color wheel placements of each scheme depicted on the bottom-right.

5.1. Monochromatic

Monochromatic schemes (from mono meaning one and chroma meaning color) utilize a single, dominant color and provide color variation only by using desaturated versions (or tints) of the dominant color. Since they rely on a single color, monochromatic schemes are easy to use in complicated designs to provide a sense of cohesion and uniformity. Because the overall scheme is simple (i.e., one color), this also allows you to include richer secondary elements, such

as images in a Facebook news feed or a variety of images on a Pinterest board. The trade-off, however, is that monochromatic designs can be boring or overbearing if highly-saturated versions of the dominant color are overused. To prevent this, use plenty of white and very lightly-saturated tints of the dominant color to offset the more highly-saturated attention areas. In the provided example (Figure 9), the navigation bars are a highly-saturated blue, so the content on the rest of the design needs to use plenty of white and very light blues for balancing.

Figure 9

Monochromatic Schemes Use a Single Dominant Color of Different Saturations

5.2. Analogous

Analogous schemes rely upon two or more nearby colors on the color wheel, generally spanning no more than one-third of the color wheel (e.g., red and blue, green and orange, cyan and violet). Since the colors are not distinct enough from one another to allow them to be placed side-by-side, plenty of white space should be used to separate instances of the two colors. Analogous schemes are more visually interesting than monochromatic schemes, because they provide more color variation, but they are also more difficult to use, because the two dominant colors must be well-separated, and any other visual elements should fit the scheme. In the provided example (Figure 10), the crimson logo and carousel are clearly separated from the blue events block, and the image in the carousel has a dominant blue color (via the woman's sweater) that roughly matches the other blues in the design. If the woman's sweater was orange or green, however, the design would struggle to be harmonious; because the design is already using so much color complexity, any more complexity introduced by the secondary elements would be distracting. Because their colors are so close to each other on the color wheel, analogous color schemes in particular may introduce contrast problems.
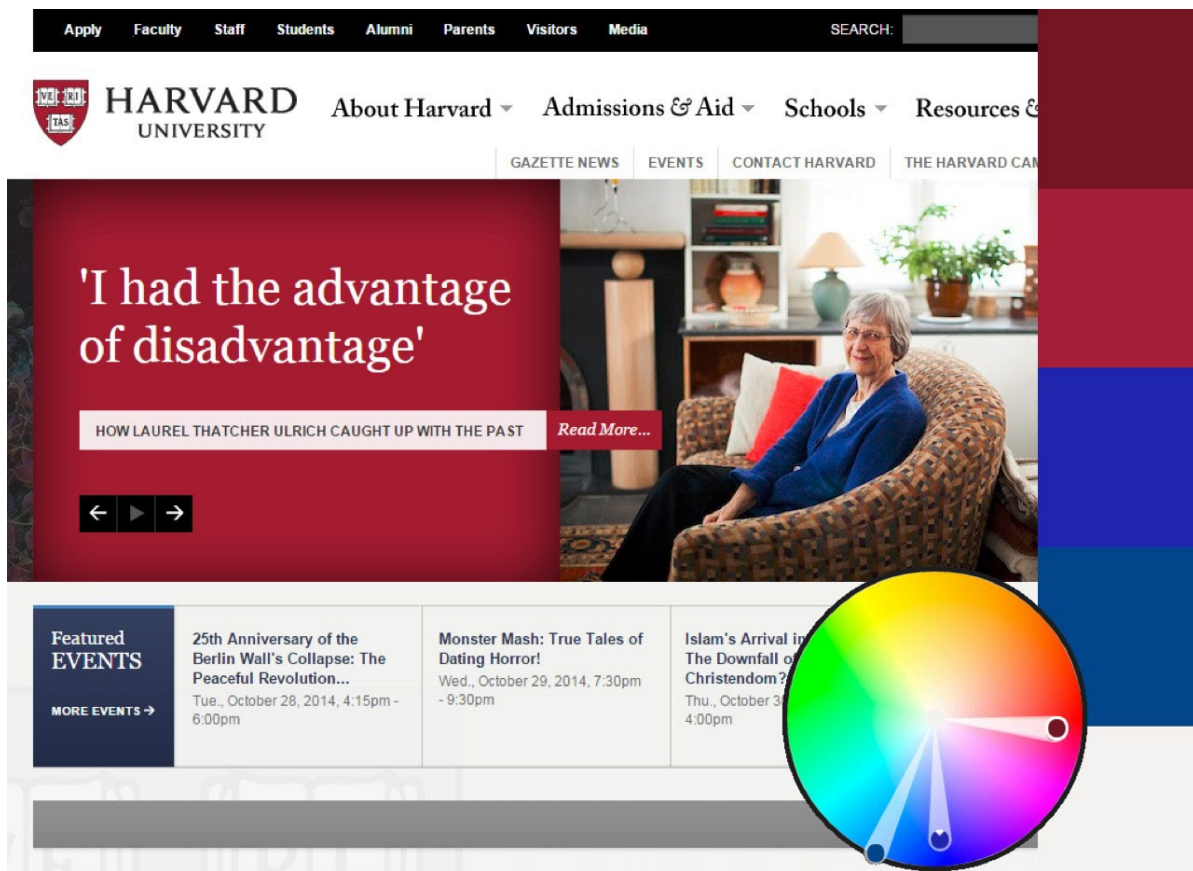
Figure 10

Analogous Schemes Use Two Dominant Colors Less Than One-Third of the Distance on the Color Wheel From One Another

5.3. Complementary

The color wheel is conceived as circular rather than linear, because colors on opposite sides when (additively) mixed will make white. These are called complementary colors (cf. Figure 11). Complementary schemes, then, use two dominant colors that are on opposite sides of the color wheel, such as blue and gold, orange and cyan, or pink and green.
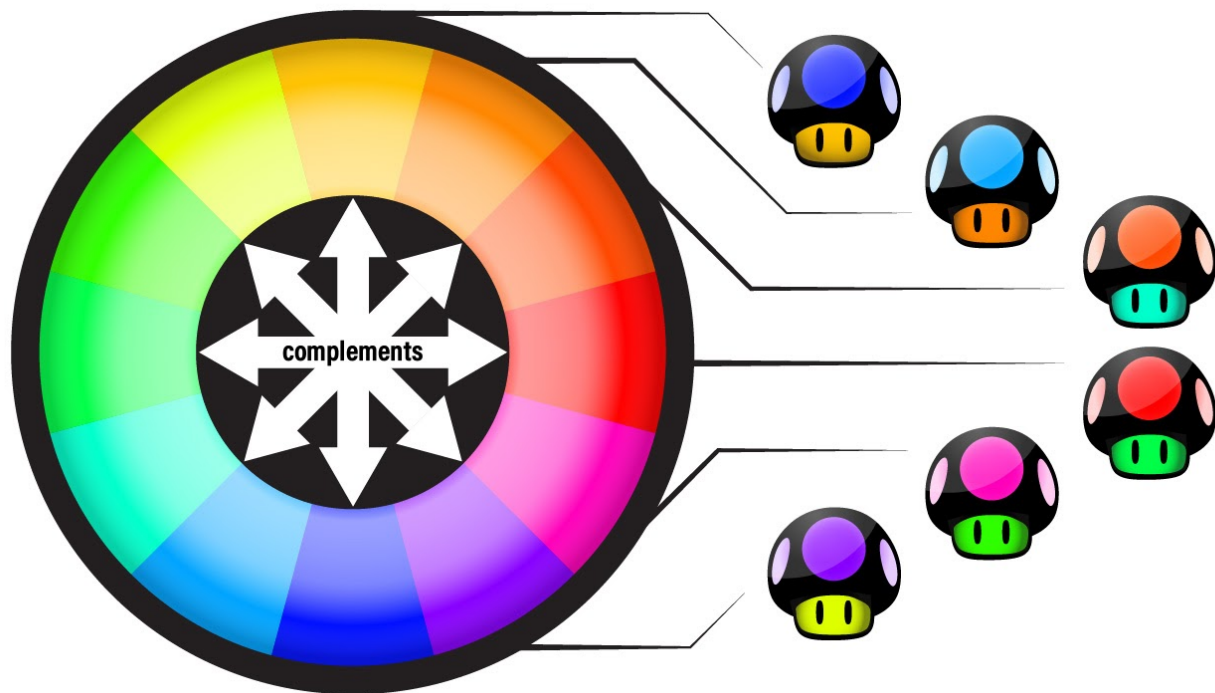
Figure 11

Complementary Colors Reside Opposite One Another on the Color Wheel

Complementary schemes are also visually interesting, but the dominant colors are distinct enough from one another that they can be used in closer proximity than can analogous colors. In the provided example (Figure 12), the orange logo and thin horizontal bars are placed nicely beside or on top of the dark blues of the menu. However, though the two colors complement each other, one should be treated as the visually dominant color, and the other should be treated as the accent (in this case, the orange is the accent). Typically, the cooler color is used as the visually dominant color, and the warmer color is used as the accent. This allows for the design to show interesting variation while also using the accent color to draw the viewer's attention to specific parts of the design, such as the logo, buttons, or content separators.
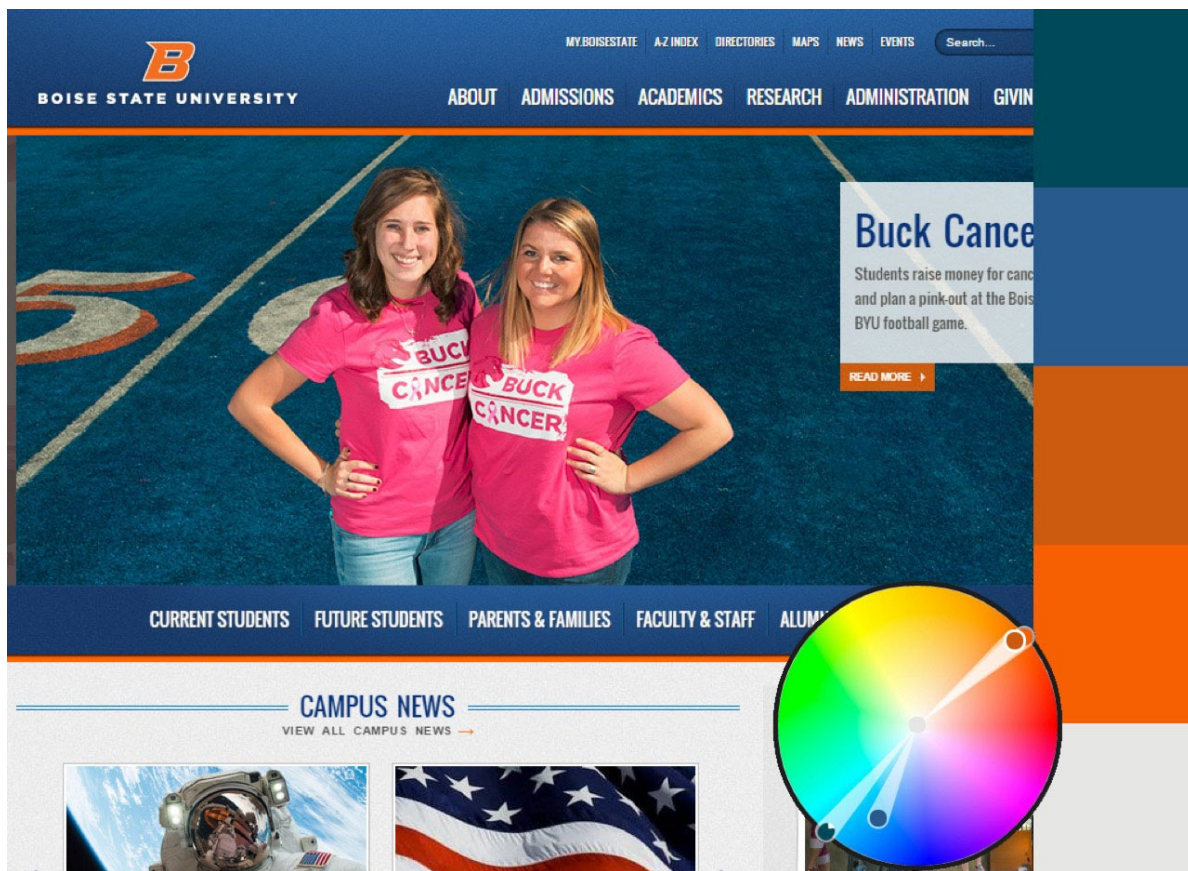
Figure 12

Complementary Schemes Use Two Dominant Colors on Opposite Sides of the Color Wheel From One Another

5.4. Complex

As the name suggests, complex schemes are the most complicated, because they use three or more dominant colors equally situated around the color wheel (e.g., blue, orange, red, and green). Because they use so much color variation, the visual space that the color takes up in the design should be very small and offset with plenty of white space. In the provided example (Figure 13), the website uses a large logo with four very different colors but offsets this by using little to no color in the rest of the design. Because of their variation, complex schemes can be very bright and interesting but can quickly become overpowering if the visual footprint of any of the colors becomes too pronounced (as in Figure 8.2).
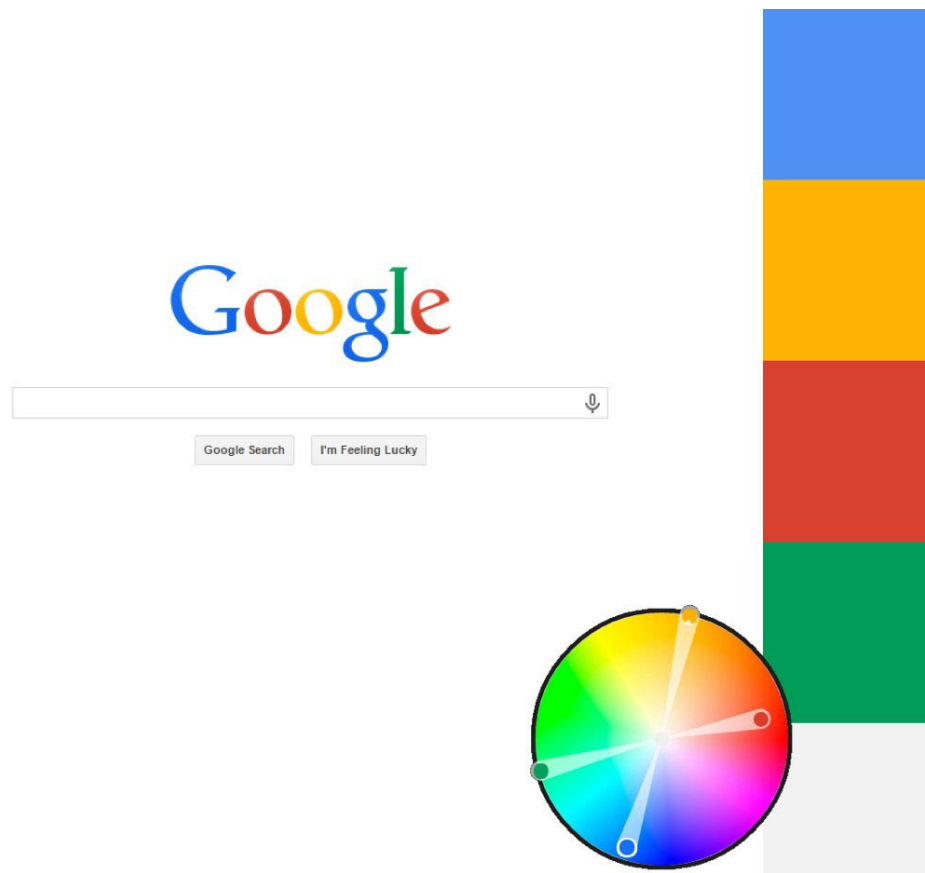
Figure 13

Complex Schemes Use Three or More Colors Equally Situated Around the Color Wheel From One Another

5.5. Achromatic

Achromatic color schemes (meaning no color) use only variations on black, white, and gray. Of all the schemes, this scheme is the easiest to use but can also be the least interesting, because it provides the least color variation. Sometimes, however, less design complexity is desirable. In the provided example (Figure 14), the overall site design uses an achromatic scheme so that when colors are used in secondary elements they will draw the attention of the viewer (in this case, products that the vendor is seeking to sell are provided in full color, while menu items and logos are muted grays). Achromatic schemes may be helpful if secondary elements are complex and rich, but without these secondary elements, the design itself would be visually boring.

Figure 14

Achromatic Schemes Use Only Black, White, and Grays

5.6. Choice and Use

Various tools are available to designers that provide color scheme examples, such as the Adobe Color website or the Google Material Palette Generator, and there are many different ways to create a color scheme. For our purposes, however, I will offer two simple techniques to create professional-looking color schemes that anyone can follow.

The first approach is to start with a single, dominant color that matches your overall emotional objective for your product—blues might be calming or sad, greens might be fresh or healthy, yellows might be fun or playful, reds might be outrageous or dangerous, etc. However, this decision might already have been made for you via institutional branding or logo decisions. Once you have this color, plug the color into a color scheming tool such as Adobe Color, and use the provided radio buttons to switch between color scheme types (e.g., analogous, monochromatic, complementary). If you want a simpler, safer design, go with a monochromatic type, and drag the circles on the color wheel to various saturation levels to give you sufficient variation in the five-color scheme. If you want something more interesting, try the complementary or analogous type. In the case of analogous, you can drag the circles around the color wheel to increase color variation, but the colors generally should not extend more than one-third (120-degrees) the circumference of the circle, lest the variation be too great. In the example image (Figure 15), I started with the Twitter logo blue (#00bbff) and found that an orange hue (#ff8400) might serve as a nice accent (complementary) color.
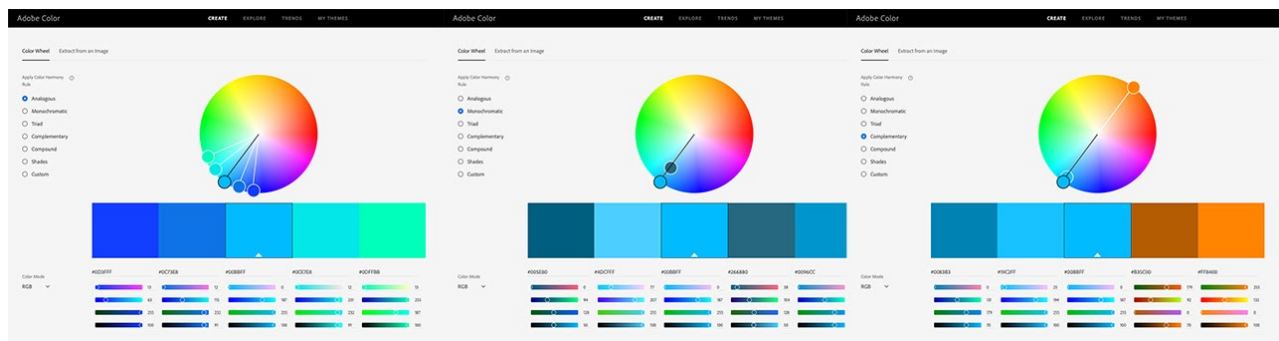
Figure 15

Choosing Different Color Scheme Types in Adobe Color From a Single Dominant Color

The second approach is to choose a picture or painting that you enjoy (preferably of a natural setting) that you feel exemplifies the emotional state you want to create with your design. Then, upload the image to Adobe Color via the "Extract from an image" feature. This will attempt to identify the dominant colors in the picture and to situate them in relation to one another in a harmonious manner. Once imported, you can click back on the color wheel to see where the colors fall and to switch between color scheme types. In the provided example (Figure 16), the image of trees in autumn generated an analogous color scheme of oranges, yellows, greens, and burnt orange.
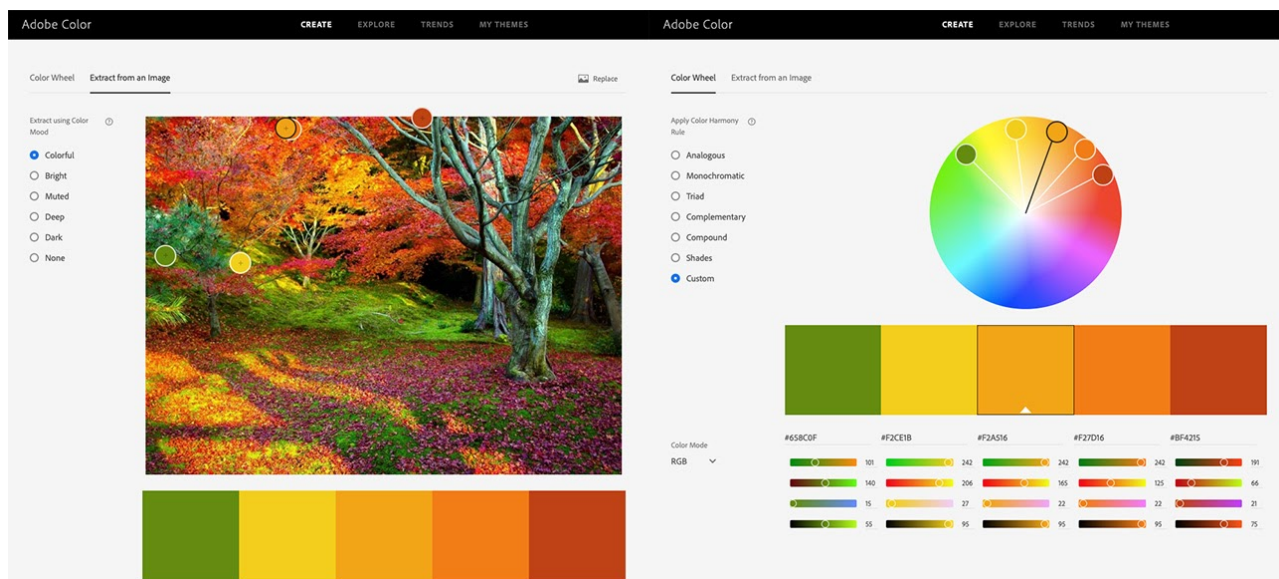
Figure 16

Extracting a Color Scheme in Adobe Color From an Existing Image

Once you have created a color scheme you are happy with, you can import the color scheme into other applications in a variety of ways. The simplest and most versatile method, however, is to simply take a screenshot and place it into your authoring tool or to manually transfer the hexadecimal codes.

6. Conclusion

This chapter has provided an overview of (a) the physics and technical notations for color, (b) scholarly literature on the relationships between color, emotion, and learning, (c) some guiding considerations on how to use color in UX design, and (d) concrete information on effectively using color schemes to improve harmony and contrast in designs. Some major takeaways for designers should include the following:

- Choose dominant colors that will influence emotions aligning with your intended design goals.
- Use colors in ways that are intentional (e.g., accentuating important content) and natural or appropriate by drawing upon users' prior experiences.
- Ensure that color contrast is sufficient and that color is used strategically to allow learners to clearly and readily identify important content and follow intended user pathways.
- Choose a color scheme that counterbalances the complexity of your content (complex content requires a simpler color scheme, while simpler content can use a more complex color scheme).
- Use whitespace and white, black, or gray text to increase contrast and to balance color-use.

By following these suggestions, UX and LX designers can create designs that increase motivation and persistence by making user experiences more pleasing, more intentional, and less frustrating.

From a research perspective, much work is still needed to help designers better understand issues of contextual color-use, differential affective influences on learners, and interactions between various colors as well as between color, content, and objectives. Because effective color-use in UX design is best described as craft (or synergy between science and art) and because learning contexts vary so greatly, it is reasonable that the most important research in this area moving forward will focus on applied, focused uses of color through iterative design cases and continual improvement. Though UX designers might not have the same obsession with color that Monet expressed, hopefully our obsession for learning will help us to more fully recognize that color is an important aspect of the learner's experience that should be better understood and more skillfully applied.

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Models and Design Frameworks for LX

This section includes six chapters exploring an assortment of models and design frameworks for LX. Drawing from a broad spectrum of views and approaches, authors in this section grapple with a range of issues relevant to conceptually grounding individual approaches and informing their design processes. Collectively, these frameworks begin to unveil the preliminary gestalt of LX as a focus area beginning to emerge in LIDT.

Sociotechnical-Pedagogical Usability for Designing and Evaluating Learner Experience in Technology-Enhanced Environments

Learning Experience Design: Challenges for Novice Designers

The Role of Needs Assessment to Validate Contextual Factors Related to User Experience Design Practices

The Design Implementation Framework: Guiding Principles for the Redesign of a Reading Comprehension Intelligent Tutoring System

From Engagement to User Experience: A Theoretical Perspective Towards Immersive Learning

Intentional Learning Design for Educational Games: A Workflow Supporting Novices and Experts

Sociotechnical-Pedagogical Usability for Designing and Evaluating Learner Experience in Technology-Enhanced Environments

Isa Jahnke, Matthew Schmidt, Minh Pham, & Kanupriya Singh

Usability Heuristics   Technological Usability   Pedagogical Usability   Social Dimension   Multi-dimensional Heuristics

Online Courses   Technology-enhanced Learning

Learner experience in technology-enhanced learning environments is often evaluated or analyzed with traditional usability heuristics, as in Nielsen (1994a, 1994b), in order to understand if a certain tool is usable or user-friendly. However, Nokelainen (2006) has established that pedagogical usability is often neglected, an approach which takes into account issues of pedagogical design such as instructions and learning tasks. In addition, the social dimension for evaluating online or hybrid learning environments is largely absent in existing usability heuristics. We analyzed relevant literature in order to develop a conceptual framework that includes the three dimensions of social (S), technological (T) and pedagogical (P) usability. In this chapter, we present this as sociotechnical-pedagogical usability. We assert this framework can serve as the basis for future researchers to advance a new set of STP heuristics for learning design. Design recommendations are provided that address social, technical and pedagogical usability for evaluating online or other formats of learning with technologies.

1. Introduction

Typically, instructors, instructional designers, and learning designers do not develop new learning technologies from scratch. Rather, when developing courses or learning materials, they make course design decisions based on existing tools or using readily-available features of broader learning management systems (e.g., Canvas, Moodle, etc.), including how to arrange content and tools in novel ways so as to positively influence learner experience in online or hybrid learning arrangements. However, learners' engagement with learning technologies in real-world usage contexts often differs from what designers anticipated when designing and planning the technology (Schmidt & Tawfik, 2018; Straub, 2017). This disconnect can lead to situations in which the potential of the learning design is not fully realized due to a variety of reasons, including: (a) learners abandoning technology due to technical problems, (b) learning designs lacking sufficient plasticity to meet diverse and sometimes unanticipated teachers' and/or learners' needs, or (c) socio-cultural contexts influencing technology adoption counter to designer intent (El-Masri & Tarhini, 2017; Gan & Balakrishnan, 2016; Orlikowski, 1991, 1996).

Increasingly, researchers of learning design are applying methods from usability and user experience (UX) research for evaluating and improving the learner experience (LX) with learning technologies (Earnshaw et al., 2018). UX and LX share much in common, particularly in terms of methodological approaches. That UX and LX share so much in common leads to challenges in differentiating the two. This is exacerbated by a general lack of accepted definition of LX to-date. Some of the factors that distinguish LX from UX relate to the goals, focus, and context of each. The three primary defining characteristics of UX are related to the user's (a) involvement, (b) interaction, and (c) observable/measurable experience with a technology or product (Tullis & Albert, 2013). Importantly, these three characteristics must be considered broadly, looking at all contexts in which the user encounters and thereby experiences the technology or product. Among the goals of user experience design (UXD) is improving the arrangement of tools or features, from the user's perspective, so as to improve the usability and UX of a digital product. The focus of UX is therefore quite broad, with applicability to any technology in any context for any user. Learner experience design (LXD), however, has a narrower focus on improving the usability and LX of only one type of technology—learning technology—from the perspective of only one type of user—the learner. While UX is applied in a broad variety of contexts, LX is applied only in learning design contexts. For a more comprehensive consideration of how LX is defined, readers are referred to the introductory chapter of this volume.

Usability evaluation is perhaps the most widely-practiced research methodology in UX. A variety of methods can be used in UX research to evaluate usability, including Nielsen's well-known heuristics (1994a, 1994b) or task-based usability methods (e.g., Hackos & Redish, 1998). These methods aim to evaluate the perceived ease-of-use of digital technologies, which subsequently presents opportunities to improve them. For an overview of usability methods, readers are referred to Schmidt et al.'s (2020a) chapter in this volume and Earnshaw and colleagues' (2018) work on UXD. However, a tension exists in that evaluation methods that focus narrowly on technological usability alone prove insufficient when applied in learning contexts (see Lim & Lee, 2007; Reeves, 1994; Silius et al., 2003). This has led to calls for usability approaches that are sensitive to pedagogical needs or "pedagogical usability" (Moore et al., 2014; Nokelainen, 2006). Furthermore, researchers in the learning sciences agree that learning is a social effort and that meaningful learning with technologies should be embedded within social group activities (Dabbagh et al., 2019). Within this frame, learning is dependent on the quality of social relations and interactions with teachers and peers (Jahnke, 2015). Studies by Jahnke et al. (2005) suggest that social interactions and social roles are equally important in fostering human-centered learning processes. However, a factor that is often overlooked when evaluating learning technologies is the social dimension (Gamage et al., 2020; Kreijns et al., 2003).

With increasing recognition in the field of learning design of the value of human-computer interaction (HCI) and daughter disciplines such as UX (Gray et al., 2020; Moore et al., 2014; Schmidt et al., 2020b), researchers and practitioners in this field are encouraged to take heed of emerging trends in these areas. There is therefore a timely and urgent need to foreground the inherent technocentric bias of usability evaluation, as the central focus of technological usability ignores factors that are critical to learning—specifically, the pedagogical and social dimensions of learner experience. Meaningful technology-mediated learning represents a complex activity system that must account for these pedagogical and social dimensions (Kaptelinin & Nardi, 2018). However, given the lack of accepted defining characteristics of LX and clear guidance on how LX differentiates itself from UX, there is a danger that usability methods, when applied in an LX context, could fail to account for these critical considerations. It therefore follows that usability evaluation of technology-enhanced learning should embrace a broader conceptualization of usability, considering (a) the social dimension, (b) the technological dimension, and (c) the pedagogical dimension. In short, we present this as sociotechnical-pedagogical usability. In the following sections, we propose and discuss a conceptual framework and associated heuristics for sociotechnical-pedagogical usability that potentially could enhance the theoretical and practical utility of usability evaluation as applied to learning technologies.

2. Conceptual Framework

Central to the intent of this chapter is a view of learning technology usage as a new social practice of instructors, teachers, and learners. New technologies naturally prompt changes to existing work and/or learning processes,

structures, and cultures. Correspondingly, introducing new technologies into learning contexts necessarily influences learning processes; it is an interwoven, co-evolutionary manifestation of complex social, technical, and pedagogical interactions (Marell-Olsson & Jahnke, 2019). Considered a 'wicked problem', researchers have been challenged by this since the emergence of sociotechnical approaches in the early 1950s to support human work through technological and organizational change (cf. Trist & Bamforth, 1951). While human-computer interaction (HCI) research investigates person-technology relationships, learning design must consider not only the technological dimension of this relationship but also how the pedagogical and social dimensions of learning are influenced by technology. As presented above, we refer to this as sociotechnical-pedagogical usability, which we expand upon in the following sections.

2.1. Toward Learner Experience Evaluation: Extending Technological Usability to Consider Social and Pedagogical Dimensions of Technology-Enhanced Learning

Generally speaking, traditional (technological) usability evaluation focuses on the user interface (UI) and how user interaction with the UI enables the user to achieve certain goals related to the tool (Nielsen, 1994a, 1994b). Nielsen and Loranger (2006) define usability as:

> How quickly people can learn to use something, how efficient they are while using it, how memorable it is, how error-prone it is, and how much users like using it. If people can't or won't use a feature, it might as well not exist (p. xvi).

Drawing from this, traditional usability evaluation or testing considers the following factors: (a) ease of use, (b) efficiency, (c) error frequency and severity, and (d) user satisfaction (Nielsen, 1994a, 1994b; Nielsen & Loranger, 2006). Usability research is concerned with the optimization of user interactions with the UI so as to enable the user to perform typical tasks, as well as aesthetic features which support a positive user experience with the system. This traditional approach to usability evaluation is known as technological usability. Technological usability is apparent in technology-enhanced learning environments. For example, instructors and learners interact with the UI features of learning management systems (i.e., navigating to resources, viewing grades, creating posts in the discussion board, submitting assignments, etc.). The technological usability of a given elearning, hybrid, or online course delivery system affects the learner experience. Systems that have higher technological usability promote better learner experiences than those with lower technological usability (Althobaiti & Mayhew, 2016; Parlangeli et al., 1999). This suggests that failing to address technological usability during the design of learning technologies introduces barriers to learner inquiry and navigation within the learning environment, thereby impacting knowledge construction.

It is clear, therefore, that technological usability is an important aspect of overall LX. However, UI interactions alone are insufficient to fully explain the overall quality of the LX because, as maintained by Rappin and colleagues (1997), "The requirements of interfaces designed to support learning are different than for interfaces designed to support performance" (p. 486). Simply because a learning system has high technological usability does not guarantee that using it will lead to a positive learning experience or promote learning outcomes. The pedagogical and social dimensions associated with the learning process also must be considered. Absent from technological usability evaluation are, for example, communication among students and teachers, content arrangement, learning level support, learning objectives, etc. (Jahnke, 2015; Lim & Lee, 2007). Learners do not only interact with a user interface when engaging with a learning system; they also interact with intentionally designed learning materials (the pedagogical) in the context of a learning community or affinity group (the social). By explicitly acknowledging in conjunction with technological considerations the pedagogical and social dimensions of learner experience, a complex and interconnected view of technology-mediated learning begins to emerge.

The perspective of the combined social and technical dimensions of technology-mediated learning, the sociotechnical, draws from sociotechnical theory (cf. Cherns, 1976, 1987; Mumford, 2000) and applies it to a learning context. Within a sociotechnical frame, learners actions and interactions with others (i.e., discussions, file sharing, chat, etc.) are mediated by learning technologies (i.e., learning management systems, serious games, etc.). These technology mediated social experiences can be characterized as human-to-human-via-computer interaction, or HHCI (Squires &

Preece, 1999). When considered from the perspective of learning, design of HHCI can have a critical impact on learning processes and learner interactions. For example, in a study by Jahnke, Ritterkamp, and Herrmann (2005), researchers highlighted how the presence or absence of access to certain tools or files directly influenced learning and interactions. Their work foregrounds the significance and dynamicity of learner roles in HHCI learning environments. Schmidt (2014) reported that social interactions in a multi-user virtual reality learning environment had to be carefully engineered using specific technology affordances, and in some ways restricted, so as to promote intended learning outcomes. His work illustrates the sometimes unpredictable nature of learners' social interactions in novel technology contexts. Key to the sociotechnical dimension, therefore, is the notion of dual optimization; that is, optimizing both the technological and the social dimensions of the learner experience.

Combined, the pedagogical and technological dimensions of technology-mediated learning, the technological-pedagogical, refer to the extent to which the tools, content, interface, and tasks in technology-mediated learning environments support learners' achievement of learning goals and objectives (Silius et al., 2003). Related to this is the concept of pedagogical usability, an approach to usability that is less frequently studied than technical usability (Nokelainen, 2006). Pedagogical usability considers the extent to which "the tools, content, interface, and tasks of the learning environments support myriad learners in various learning contexts according to selected pedagogical objectives" (Moore et al., 2014, p. 150). This approach to usability evaluation is uniquely needed in technology-mediated learning contexts because it focuses primarily on the design of learning tasks within a user interface, not on the interface alone. A variety of pedagogical usability frameworks and heuristic checklists for web-based learning evaluation have been established in the literature (cf., Albion, 1999; Horila et al., 2002; Lim & Lee, 2007; Moore et al., 2014; Nokelainen, 2006; Quinn, 1996; Reeves, 1994; Silius et al., 2003; Squires & Preece, 1996, 1999). Frameworks and checklists like these enable learning designers to interrogate the features and affordances of a given learning technology that positively influence learning. By extension, this can result in improvements to a given learning design and to more general heuristics and principles of how to design quality technology-mediated learning. Importantly, this has ramifications for instantiation and extension of learning theory (McKenney & Reeves, 2018). Central to pedagogical usability is the interplay of technology and pedagogy, suggesting that an ecological perspective is needed in the design of technology-mediated learning.

3. Method

Having established three dimensions of learner experience in the sections above (the technological, the social, and the pedagogical), the question arises as to how these dimensions might be evaluated in practice. Nokelainen's (2006) work of pedagogical usability is relevant to this in that he systematically identified and analyzed the evaluation criteria/heuristics from eight sources to support his evaluation framework. However, his work centered around pedagogical usability alone, whereas we are interested in the three dimensions of the technological, the social, and the pedagogical. Further, his work of pedagogical is nearly 15 years old, and a variety of researchers have extended this work since. We therefore sought to analyze and update Nokelainen's work to uncover and extend associated evaluation criteria. To this end, we performed a targeted literature review to identify relevant articles that have been published since 2006. This review led to identification of five articles, in addition to the eight articles from Nokelainen. This corpus of 13 articles was analyzed to identify evaluation criteria, which were then summarized and synthesized. We present in Table 1 below the evaluation criteria that were discovered in our literature review related to usability heuristics for technology-mediated learning (as adapted and updated from Nokelainen, 2006).

Table 1
Social, Technological, and Pedagogical Evaluation Criteria Drawn From the Literature
(as adapted and updated from Nokelainen, 2006)
*Identified by Nokelainen (2006)

Author(s), Year	Dimension(s) of learner	Title	Criteria

		experience	
Nielsen, 1994a, 1994b*	Technological	10 Usability Heuristics for User Interface Design	1. Visibility of system status 2. Match between system and the real world 3. User control and freedom 4. Consistency and standards 5. Error prevention 6. Recognition rather than recall 7. Flexibility and efficiency of use 8. Aesthetic and minimalist design 9. Help users recognize, diagnose, and recover from errors 10. Help and documentation
Squires & Preece, 1999*	Technological-Pedagogical	Predicting quality in educational software	1. Appropriate levels of learner control 2. Navigational fidelity 3. Match between designer and learner models 4. Prevention of peripheral cognitive errors 5. Understandable and meaningful symbolic representation 6. Support personally significant approaches to learning 7. Strategies for the cognitive error recognition, diagnosis and recovery 8. Match with curriculum
Albion, 1999*	Technical-Pedagogical	Heuristic evaluation of educational multimedia: from theory to practice	1. Establishment of context 2. Relevance to professional practice 3. Representation of professional responses to issues 4. Relevance of reference materials 5. Presentation of video resources 6. Assistance is supportive rather than prescriptive 7. Materials are engaging 8. Presentation of resources 9. Overall effectiveness of materials
Reeves, 1994*	Mainly pedagogical	Evaluating what really matters in computer-based education	1. Learner control 2. Pedagogical philosophy 3. Underlying psychology 4. Goal orientation 5. Experimental value (authenticity) 6. Teacher role 7. Program flexibility 8. Value of errors 9. Cooperative learning 10. Motivation 11. Epistemology 12. User activity 13. Accommodation of individual differences (scaffolding) 14. Cultural sensitivity

Quinn, 1996*	Mainly pedagogical	Pragmatic evaluation: lessons from usability	1. Clear goals and objectives 2. Context meaningful to domain and learner 3. Content clearly and multiply represented and multiply navigable 4. Activities scaffolded 5. Elicit learner understandings 6. Formative evaluation 7. Performance should be 'criteria-referenced' 8. Support for transference and acquiring 'self-learning' skills 9. Support for collaborative learning
Squires & Preece, 1996*	Technological, Pedagogical	Usability and learning: evaluating educational software	1. Specific learning tasks 2. General learning tasks 3. Application operation tasks 4. General system operation tasks
Horila et al., 2002*	Technological, Pedagogical	Criteria for the pedagogical usability, version 1.0	1. Learnability 2. Graphics and layout 3. Technical requirements 4. Intuitive efficiency 5. Suitability for different learners and different situations 6. Ease of use: technical and pedagogical approach 7. Interactivity 8. Objectiveness 9. Sociality 10. Motivation 11. Added value for teaching
Silius et al., 2003*	Pedagogical	A multidisciplinary tool for the evaluation of usability, pedagogical usability, accessibility and informational quality of web-based courses	1. Support for organization (organization of teaching, organization of studying, support for education training portal for different user groups) 2. Support for learning and tutoring process (learning process, tutoring process, achievement of learning objects influenced by motivation, cooperation, collaboration, reflection, knowledge construction, intention, activation, authenticity, contextualization, transfer) 3. Support for development of learning skills (self-direction, interaction with other actors, and learners' autonomy)

Nokelainen, 2006	Mainly pedagogical	An empirical assessment of pedagogical usability criteria for digital learning material with elementary school students	1. Learner control 2. Learning activity 3. Cooperative/ collaborative learning 4. Goal orientation 5. Applicability 6. Added value 7. Motivation 8. Valuation of previous knowledge 9. Flexibility 10. Feedback
Lim & Lee, 2007	Pedagogical	Pedagogical usability checklist for ESL/EFL e-learning websites	1. Instruction 2. Contents 3. Tasks 4. Learner variables 5. Interactions 6. Evaluations
Moore et al., 2014	Pedagogical	Designing CMS courses from a pedagogical usability perspective	1. Content organization 2. Information load and cognitive load 3. Assessment
Jahnke, 2015	Pedagogical, Social	Digital Didactical Designs	1. Teaching/learning objectives 2. Learning activities 3. Forms of assessment 4. Support of interaction 5. Communication and roles among students and teacher
Marell-Olsson et al., 2019	Pedagogical, Social	Wearable Technology in a Dentistry Study Program	1. Communication support 2. Information support 3. Social relations 4. Student-centered 5. Reflective feedback for learning, clear purpose, added value

4. Results

The various criteria presented in Table 1 highlight the intersections between the technological, pedagogical, and social dimensions of technology-mediated learning systems evaluation. We analyzed all criteria presented in Table 1 to identify salient points of convergence and divergence. For the analysis we used categorical aggregation to code similar items into the categories (Creswell, 2016). Drawing from our analysis of those criteria, we synthesized our findings along key dimensions related to usability evaluation that considers not only the technological but also the social and pedagogical aspects of learner experience. We coin this multidimensional usability framework sociotechnical-pedagogical usability. An overview of the dimensions and coded criteria are provided below in Table 2.

Table 2

Coded Items Revealing the Three Dimensions of Social, Technological and Pedagogical Usability

Note. From a total of 97 items in Table 1, only three items were coded multiple times (i.e., into three different categories) (sum of 100 items).

Dimension	# of coded items	Categories of coded items (#)
Social	13	Collaboration (4)
		Communication (4)
		Roles, relationships (3)
		Sociality, social interactivity (2)
Technology	20	Nielsen's 10 heuristics, navigation, learnability, prevention of cognitive errors
Pedagogical	61	Learning activities (19)
		Learner context, motivation (9)
		Content arrangement, material organization (9)
		Assessment (7)
		Goals, objectives (6)
		Learner control (6)
		Assignments, tasks (5)
Meta-category (misc.)	6	e.g., Epistemology, added value for teaching, objectiveness, match between designer and learner models

In this section, we have presented our conceptual framework and explicated the dimensions of evaluation that are central to sociotechnical-pedagogical usability. We now turn to the potential implications of this on a preliminary conceptual model.

5. Discussion

By considering the three dimensions of usability identified by our literature review—namely, the technical, the social, and the pedagogical—we witness the emergence of an interconnected and interdependent framework that extends traditionally narrow views of technical usability towards a more holistic view that acknowledges the centrality of the pedagogical and social aspects of learning. In this chapter, we identified evaluation dimensions drawn from social, technical and pedagogical aspects of learner experience to better understand the overall learner experience in technology-mediated learning environments. These three dimensions are not entirely new; however, we advocate for combining them and applying them. This can be beneficial in identifying potential design flaws when evaluating

technology-mediated learning designs and then remediating those flaws. We assert that the congruence of these three dimensions in learning designs will promote positive learning experiences. This congruence is represented in Figure 1.
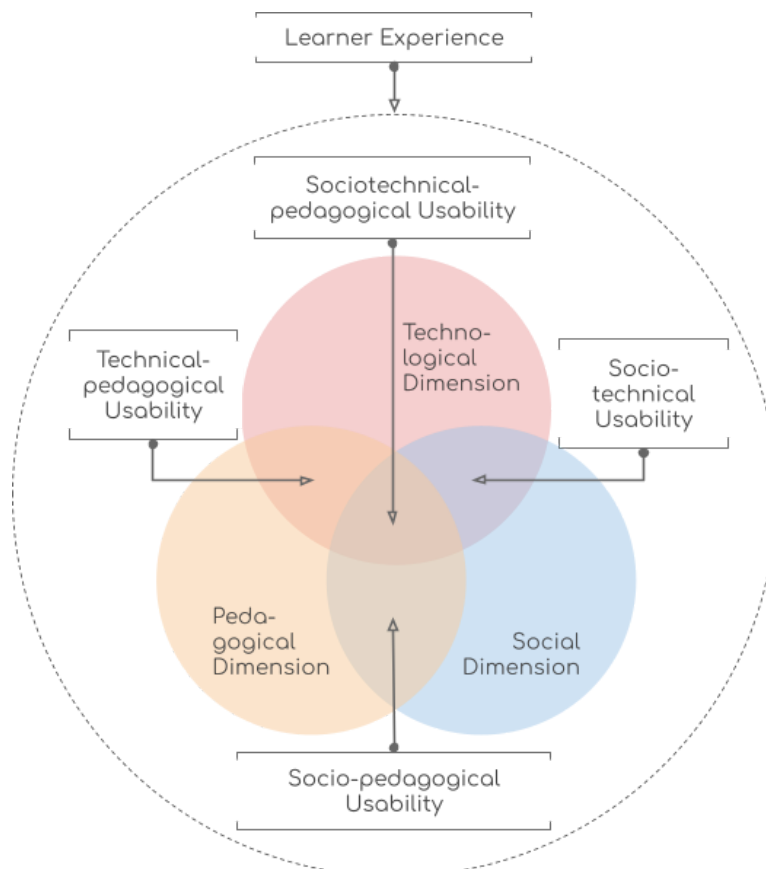
Figure 1

Multi-Dimensional Usability Framework in the Context of Learner Experience

Figure 1 illustrates the intersections of the three separate dimensions of the social, pedagogical, and technological dimensions. First is socio-technical usability, which involves the technological and the social dimensions. It uniquely explains how the technology dimension (e.g., Nielsen, 1994b) and the social dimension are interdependent. The social dimension consists of learner or teacher communication and collaboration including social presence and social relationships to be built for learning, which cannot be achieved without a usable technology tool. Technological usability itself is inherently necessary but insufficient for a technology-enhanced learning environment. Instead, usability and the user-friendliness of online social presence provides the critical foundation for developing a community of learners, promoting active learning, and engaging students in learning.

Second, socio-pedagogical usability is situated at the intersection of the social and the pedagogical dimension and focuses attention on how to balance social and pedagogical factors in learning design. The pedagogical dimension involves instruction and learner tasks or assignments. The pedagogical dimension includes learning/instructional strategies, clear scaffolding and supports, instructions, and meaningful learning activities. While the pedagogical dimension is necessary for active student-centered learning, the social dimension is necessary to foster a positive learner experience. The social dimension includes sociality and social presence in online or hybrid learning.

Third, the technical-pedagogical dimension is positioned at the intersection of the technological and pedagogical dimension and emphasizes integration of usable technology with usable pedagogy. While technology usability is necessary but not sufficient for the whole learner experience, the pedagogical dimension considers (a) the instructor or teacher (or instructional designer) perspective on how to describe and distribute teaching goals and objectives, (b) the

learner activities and assignments, and (c) the formative and summative assessment (e.g., rubrics) for each activity. In summary, the intersections of the three dimensions that we call socio-technical-pedagogical usability show how they affect each other, but even more importantly, by explicitly naming them and describing their interrelated properties, learning/instructional designers and/or instructors are provided a generative framework for what to design when engaging in the design of active student-centered learning with technologies.

Drawing from our synthesis of the social, technological, and pedagogical evaluation dimensions outlined in Table 1 and explicated in Figure 1, we now turn to establishing design recommendations (Table 3). Collectively, these design recommendations contribute to the field's understanding of learning experience design in that they (a) acknowledge the utility of usability evaluation to exploring and assessing learner experience; (b) provide a nuanced approach toward conceptions of usability in the context of learning design; (c) stratify learner experience in technology-mediated learning contexts across the social, technological, and pedagogical dimensions; and (d) provide a foundation upon which future researchers can build and extend.

Table 3

Socio-Technical-Pedagogical Usability Design Recommendations for Hybrid or Online Courses

Usability dimension	Design recommendations for supporting learner experience in active student-centered learning environments
Social	Building social relationships and foster active learning roles of students by communication and online social presence: • Prominent social presence of instructor through variety of actions (e.g., discussion boards, announcement activities, emails); • Introduction of instructor through a visual video, or image combined with text; • Introduction discussion post in the beginning of the course for students to prepare a video or image with text to introduce themselves to the class; • Instructor-learner meetings once during the course to share feedback and thoughts; • Instructor feedback for each student at least once a week; • Inclusion of group learning activities for enhancing sense of belonging; • Refrain from conveying any negative or demotivating message to students.
Technological	Technology usability and user-friendliness of tools: • Smooth integration and easy access to multimedia features; • Instruction on how to use multimedia technologies; • Contact details for technical support (support for recovery from errors); • Readily available instructions on how to resolve common technical issues; • Transcription for audio and video multimedia content for easy access to information; • Easy to locate and understand navigation guidelines; • In general, apply Nielsen's usability heuristics.
Pedagogical	Learning goals and objectives • Well-worded goals for entire course and weekly objectives; • Weekly objectives aligned with weekly content and learning activities and assignments; • Easy to locate. Content organization

- Logical categorization of weekly content with an intuitive sequence;
- Shortcuts to different categories of the course, such as grades, syllabus, assignments provided from the main navigation menu;
- Inclusion of interactive multimedia and visual information through voice, music, animation, real environment clips or images;
- Instructional tutorial on how to navigate through the structure, complete activities;
- Avoid multiple topics in a single week.

Learning activities, tasks, instructions

- Consistency in content load;
- Clear and detailed instructions on how to complete different activities, such as replying to discussion posts and use of quizzes;
- Design for active, student-centered learning (understanding, applying, creation);
- Learning activities bridge classroom learning and real world;
- Distance learners apply new knowledge where they live (the importance of place);
- Time flexibility to accommodate students completing their activities;
- Connecting the learning content with the student context real world.

Process-based assessment by using rubrics

- Student-centered: learners create artifacts and receive formative assessment how to improve the work;
- Fostering of motivation by including assessments through personal one-to-one feedback;
- Use of meaningful questions in quizzes or other activities related to goals and content;
- Design assessment activities for higher order learning skills (e.g., analysis, application) in addition to lower order thinking (e.g., recall and recognition) to challenge and engage different skill levels of learners;
- Visible interaction with students on discussion boards by acknowledging good replies and providing feedback to answers which can be improved.

6. Conclusion

Traditionally, learner experience studies have focused principally on technological usability. More recently, heuristics have begun to consider pedagogical perspectives. However, largely absent from learner experience research are considerations of the social dimension. In this chapter, we have foregrounded the importance of all three dimensions—the social, the technological, and the pedagogical—and have aligned all three dimensions into an operable framework for conducting learner experience research: in short, sociotechnical-pedagogical usability. We encourage future researchers to critique, apply, and extend the provisional framework and heuristics provided herein, with the hope that we, as a field, can move towards the development of a cohesive set of sociotechnical-pedagogical usability heuristics.

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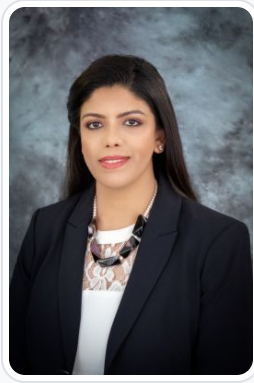
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Learning Experience Design: Challenges for Novice Designers

Yoo Kyung Chang & Jin Kuwata

Instructional Design   Design Thinking   Learning Experience   Design Expertise   Problem Solving Process

Human-centered

Learning Experience Design (LXD), defined as the practice of designing learning as a human-centered experience leading to a desired goal, poses many challenges to novice designers. This chapter presents common challenges experienced by novice learning designers through the lens of design problem solving as well as expert suggestions on how to address the challenges. Without expert knowledge and schema, novice designers experience difficulty conceptualizing and analyzing complex learning problems. An insufficient or erroneous definition of the learners and contextual needs poses further challenges in drawing effective design solutions grounded in learning theory and design principles that flexibly accommodate multiple learning experiences. It is important that novice designers develop their identity as a designer as they learn to think and problem-solve as one.

1. Introduction

The way we conceptualize, define, and practice learning design has changed over the decades in relation to social and cultural demands for educational or training needs, technology, and learning theories (Clark, 2002). Different assumptions about how people learn and how to best support it have transformed (Boling & Smith, 2018; Jonassen, 1991; Molenda, 1997; Wilson, 2005), including the epistemological foundation such as constructivism and instructional design practice such as aesthetic design. Learning design is conceptualized as a scientific approach, a systematic process, or development of creative and informed solutions around possibilities and constraints within the design space towards concrete goals (Reiser, 2001).

In the traditional field of learning design, Instructional Design (ID), over hundreds of ID models have been developed in the last five decades which represents our struggle to understand, define, and shape the way we effectively design learning (Boling & Smith, 2018). Despite the overwhelming number of diverse ID models developed to describe and inform practice, the actual practice is still dominated by the ADDIE (Analysis, Design, Development, Implementation, Evaluation) Framework which many practitioners implement as a systematic, linear, and rule-based procedure (Hokanson & Miller, 2009; Silber, 2007). Such approaches lead to generalized learning goals and experiences that well accommodates behaviorist or cognitivist learning, but leave little flexibility to address the diverse needs of learners and the learning context, as emphasized by current understanding of how people learn (Ertmer & Newby, 2013; Hokanson &

Miller, 2009; Silber, 2007). A number of researchers called for the need to revise how we conceptualize, teach, and practice ID (Boling & Smith, 2018; Jonassen, 2008; Kirschner et al., 2002; Nelson et al., 1988; Silber, 2007).

Learning Experience Design (LXD) is an attempt to integrate design practice from related design fields such as human-computer interaction (HCI), architecture, product design, and software design with instructional design (Boling & Smith, 2018). Specifically, LXD has its roots in user-experience design (UXD). While there is no consensus on how to define UXD (Kou & Gray, 2019; Law et al., 2009), it is commonly conceptualized as an interaction between the user, the system, and the context of experience (Lallemand et al., 2015). Similarly, the practice of LXD from the UXD perspective focuses on ensuring the functionality of the system, as well as the ease and satisfaction of the experience. This approach addresses the limitations in current practice of ID where there is relatively less emphasis on the experience of learning (Boling & Smith, 2018). However, with a lack of consensus around the definition of UXD, much less LXD, there is a need to provide a concrete definition of LXD to guide the conceptualization and practice of learning design.

Novice designers in the learning domain commonly exhibit difficulties understanding how learning occurs through different perspectives (i.e., learning theories) and how to best support learning through design. For example, novice designers experience difficulties engaging in the complex design process that entails understanding the underlying needs of the learners in the given learning context, drawing design solutions based on appropriate design principles, as well as evaluating and iterating the design solution (Ertmer et al., 2009; Rowland, 1992, 1993; Silber, 2007). A clear framework to understand the nature and process of learning design and concrete suggestions to implement during the design practice is needed.

As a response to challenges facing novice LX designers, the goal of this chapter is to (a) present a working definition of LXD and (b) offer suggestions for novice learning experience designers on how to approach LXD based on the expertise literature. The chapter approaches LXD as a complex, ill-structured problem-solving endeavor for multiple reasons. Design is studied as a problem-solving process in multiple disciplines including engineering design (Crismond & Adams, 2012), learning design (Jonassen, 2008), and design in general (Cross, 2004), with a wealth of research on problem solving to support the inquiry. Most importantly, problem-solving can provide a concrete framework to articulate and guide the practical challenges that novice designers experience beyond a conceptual understanding of the field. The assumption is that LXD challenges are ill-structured problems that necessitate flexible, creative solutions to address the dynamically emerging needs of the learners in relation to the learning context (Nelson et al., 1988). The chapter first presents a working definition of learning experience design. The implications of the defining characteristics of LXD on the practice of design are discussed especially in comparison to traditional perspectives of instructional design. Then, commonly observed challenges as experienced by novice LX designers are discussed with expert suggestions on how to address the challenges.

2. Defining Learning Experience Design

The chapter presents a working definition of *learning experience design* as a practice of designing learning as a human-centered experience that leads to a desired goal. The defining characteristics of LXD are not exclusive but are equally important components of ID and UXD. However, those constructs are conceptualized, defined, and practiced differently under LXD.

2.1. Learning Experience

Under LXD, the focus of design is the learning experience rather than the learning tools or materials. Learning experience includes the cognitive engagement with the learning tasks, as well as the affective response and subsequent engagement with the learning context (Parrish, 2009).

ID focuses on the design of learning tools or materials around subject matter, instructional methodology, learners, and the learning context as part of the carefully constrained instructional system (Parrish, 2009). Instead, LXD expands the design and recognizes multiple, equally effective learning experiences to support diverse and emerging needs of the

learners and the learning context (Mager, 1997). LXD draws the designer's attention to the quality of the learning experience, not just the goals accomplished as a result.

2.2. Human-Centered

Understanding the varied parameters people carry into a learning endeavor and how those variables affect learning are the considerations of traditional ID. However, LXD extends such considerations with learner-centered design, shifting focus from instruction to learner-driven construction of a human experience that is meaningful, engaging, and satisfying (Wilson, 2005). Human-centered LXD includes empathetic understanding of the learner, the sociocultural and technical context in which they are embedded, and the individual and socially mediated meaning making process as driven by the learners.

Creating such personal experience for learners requires imagination and empathy by the designers (Parrish, 2009), and integration of research from the HCI/UX fields. The focus of LXD should go beyond providing the actionable options according to the learners' preferences (Garrett, 2010). It should allow such satisfaction through personally meaningful learning experiences. The resulting design is a complex system consisting of bidirectional and reciprocal interaction between multiple factors that allows for meaningful, authentic, and learner-directed experience (Domagk et al., 2010). Therefore, LXD should provide opportunities and support for highly personal experiences, empathy towards the learners, and human-centeredness that considers not only what the learners want, but what they actually need in order to deeply engage with the learning experience to accomplish the learning goals.

2.3. Goal-Oriented

Outcome goals are important, but equally important are goals that guide the design to ensure that learners find meaning and relevance in those outcomes. The purpose of design in LXD is to connect the goals of the individual with the contextual learning goal through meaningful engagement led by the learners. That is, each learner should come to understand why and how the process they are engaged with relates to their own motivations, goals, and values.

When a process engaging a learner aligns with the trajectory of their individual purpose, learning is enhanced and results in longer, more profound learning outcomes (Bransford et al., 2000; National Academies of Sciences, Engineering, and Medicine, 2018; Parrish, 2009). As learners negotiate between personal and contextual learning goals, the designer must be attuned to the complex and dynamic interactions that take place between the learner's internal influences (e.g., cognitive, emotional, social, cultural, political and aesthetic qualities) (Wilson, 2005), their behaviors, and the learning environment.

In comparison, traditional ID emphasizes contextually assigned learning goals to promote acquisition of knowledge and skills as learning outcomes. Consequently, ID takes a rule-based approach by following linear paths as prescribed by ID models, leaving less room for personally meaningful experiences.

2.4. Design

At heart, learning design is an ill-structured problem-solving activity (Ertmer et al., 2008, 2009; Jonassen, 1997; Silber, 2007; Tracey & Boling, 2014). According to Jonassen and Tessmer (1996), ill-structured problem-solving such as LXD is not only the application of domain and structural knowledge, but also the application of knowledge to solve design problems and articulation of connected ideas through the creation of arguments, analogies, and inferences. Designers should have a developed sense of self as problem solver, through control and understanding of their personal motivations, attitudes, biases, and ideas.

Thus, the responsibility of the LX designer is considerable. LX designers must identify, define, and design opportunities to engage learners in meaningful and varied learning experiences. Also, they must reason how to provide supporting scaffolds as learners engage in multiple paths to arrive at their own relevant understandings (Bransford et al., 2000).

LX designers do not fully determine or control the learning experience. Rather, they design, prepare and integrate appropriate resources and design elements that support diverse but equally effective learning experiences. The design

elements may include tools and materials of diverse media, social interactions, and making of artifacts to support and challenge their meaning making process. LX designers: a) understand the opportunities and constraints of the learning problem through analysis of the learners, learning contexts, and the learning tasks; b) make decisions based on empirical evidence on how learning experiences emerge through interaction amongst these factors; and c) test and iterate the design decisions (Jonassen, 2008; Silber, 2007).

3. Novices and Experts: Problem-Solving and LXD

Several decades of research on instructional design expertise distinguishes some fundamental differences between novice and expert designers. Novice instructional designers often make fundamental and recurring mistakes that challenge their design practice (Ertmer et al., 2008, 2009; Ertmer & Stepich, 2005; Rowland 1992, 1993; Silber, 2007). Alternatively, expert designer thinking processes share many similarities across domains (e.g., instructional design, architecture, engineering, etc.) (Haupt, 2015; McMahon, 2009; Silber, 2007; York & Ertmer, 2016).

The complex and holistic approach to LXD poses added challenges to the novice designers regarding their prior assumptions and practice of design. With the assumption that LXD is about ill-structured problem solving, this section presents relevant findings from empirical research on design expertise, contextualized as implications for key aspects of LXD. The challenges and suggestions are discussed along the main components of problem solving: a) problem generation, b) problem-solving process, and c) solution generation and the implications under a working definition of LXD.

We open the section with two visual stories, caricatures of the novice (Figure 1) and expert (Figure 2) designer, followed by a discussion that highlights key moments in relation to different problem-solving approaches and our working definition of LXD. These stories are meant to depict common challenges designers face, how they might approach them, and how different thought processes manifest as design decisions and actions, without the intention of being definitive. Designers at various stages in their professional development are expected to bring different understandings, insights, abilities, strengths, and weaknesses to the design process.
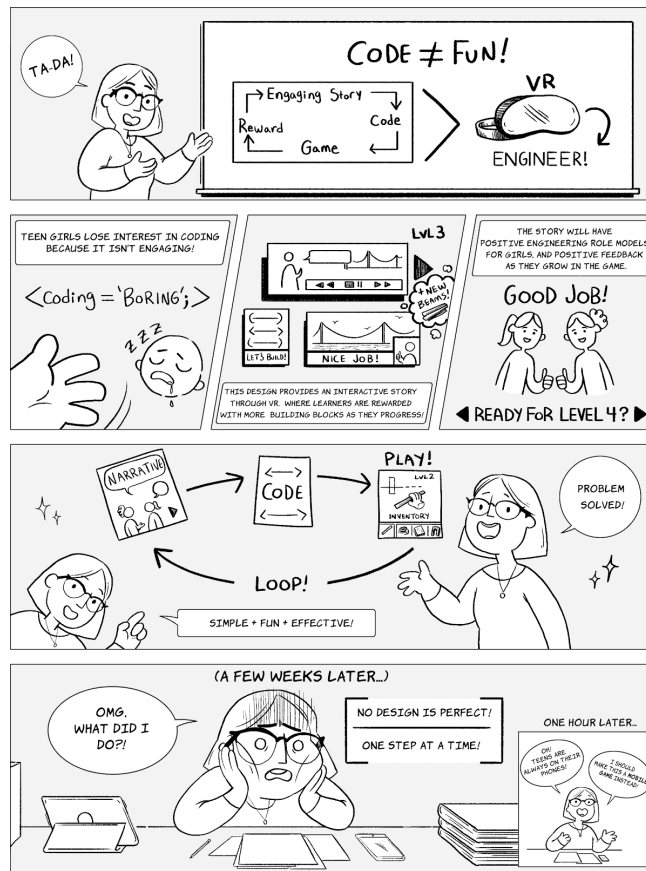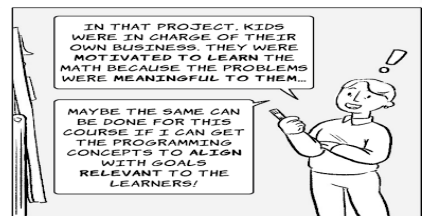
Figure 1

The Novice Story: How Novice Designers Problem-Solve Learning Designs
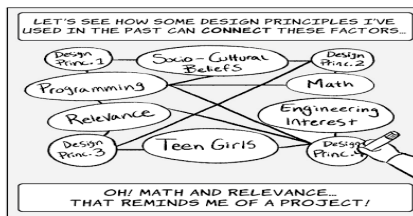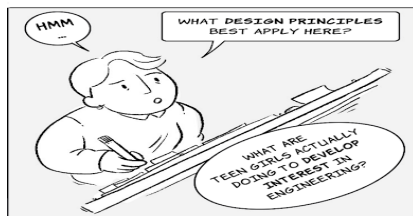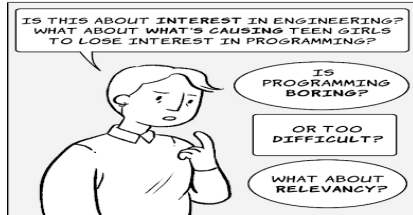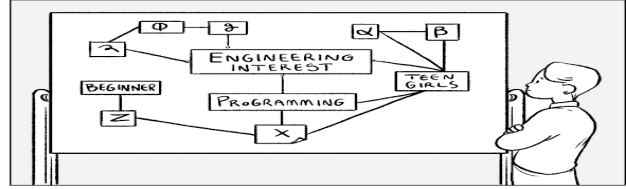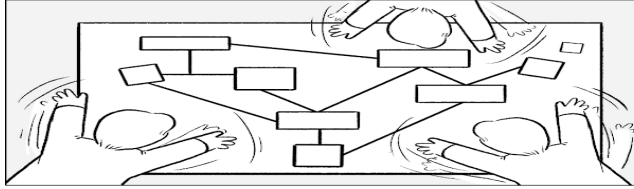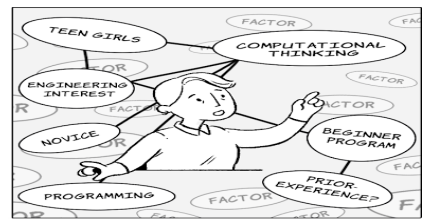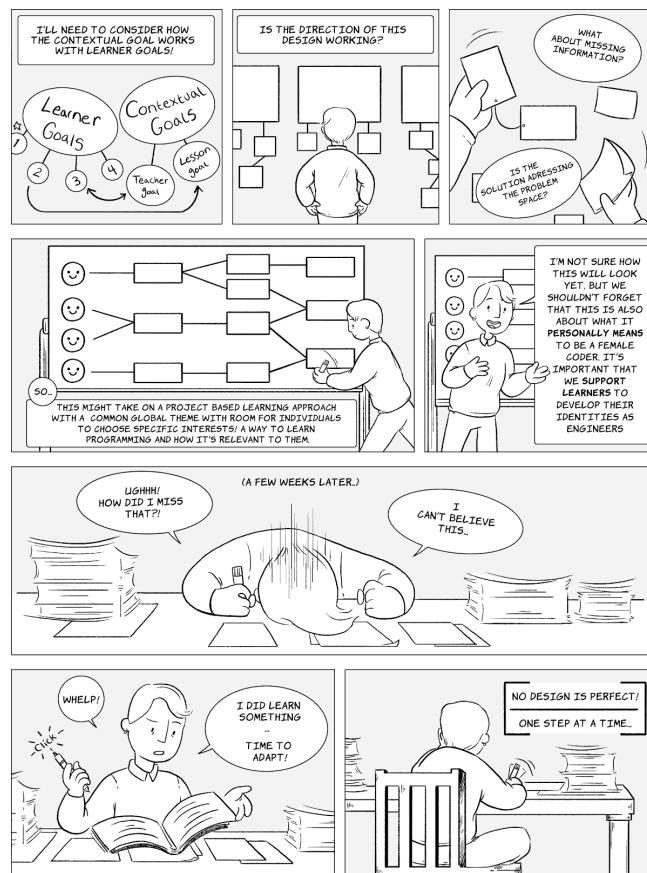
Figure 2

The Expert Story: How Expert Designers Problem-Solve Learning Designs

3.1. Problem Generation

LXD requires designers to create *learning experiences*, defined as experiences through which learners construct meaningful understanding. The nature of the problem that designers must solve goes beyond identifying and sequencing the summative parts of knowledge and understanding necessary to reach the end learning outcome. The problem-space that needs to be generated and articulated in the designer's mind is fundamentally more sophisticated. It necessitates understanding that exhibits both depth and breadth of the complex and dynamic factors that influence learners. The learning problem shifts from "What do learners need to know and do?" (i.e., learning outcome) to "How do we support learners in negotiating meaning?" (i.e., learning experience). To achieve this, designers are challenged to see and identify relationships between the myriad of influences that learners' confront, to define the parameters of the problem, to carve out their working space, and to remain mindful of the nuances that make each learner unique.

Novice designers exhibit difficulty identifying and defining meaningful problems comprehensively, deeply, and accurately (Ellis & Levy, 2010; Ertmer et al., 2008, 2009; Mosely et al., 2018). Novices tend to summarize and repeat given information (Ertmer & Stepich, 2005), without diving beyond the surface features or considering important issues and qualities of the problem (Sugar, 2001; York & Ertmer, 2016). They interpret givens as fixed in-boundaries of their problem-solving endeavors (Rowland, 1992) without questioning the accuracy of information.

In our caricature of the novice designer (Figure 1) the ability to focus only on the literal/surface elements (i.e., programming, interest, engineering, and demographics) limits: a) areas that the novice will pursue analysis, b) recognition of the different conceptual learning issues at hand, and c) the depth of cohesion between important factors. Consequently, this impacts how our novice defines the problem space. For example, a novice designer's analysis and definition of the problem space may not consider the learning experience despite its importance among factors such as the learner, learning context, and design. Similarly, a narrow understanding of the learners beyond generalizable traits

and characteristics may result in a one-size-fits-all solution that lacks considerations for the human-centeredness of LXD. Our novice relies on sparse domain knowledge and personal experiences, instead of further investigation with experts or external resources, introducing biases and unfounded insights to the problem.

In contrast, experts approach problem generation differently (Figure 2). They analyze given information skeptically as both inaccurate and inadequate (Rowland, 1992). They synthesize their own conceptualizations of a problem space consisting of features and information patterns bounded by coherent relationships, based on their prior knowledge and experience (Bransford et al., 1999; Ertmer & Stepich, 2005; Haupt, 2015). Subsequently, they use this information to see beyond the surface of a problem, by making inferences that not only fill in the missing gaps of a problem, but elucidate the underlying conceptual principles that govern the present phenomenon (Ertmer & Stepich, 2005; Haupt, 2015; Mosely et al., 2018; Rowland, 1992). That is, experts challenge their assumptions and aren't bound by original, literal, and perceived constraints which help them see the deep-structures of a given problem.

In the story, our expert designer conceptualizes an array of different factors and connections that may be of importance to the resulting learning experience. The expert also questions specific parameters (e.g., interest), to deliberate over the deeper nature and meaning behind the phenomenon, leading to human-centered inquiries. This subsequently allows for flexible learning paths as part of the forthcoming designed experience. The expert synthesizes the problem-space primarily in reference to the theoretical and practical knowledge gained from prior experience. However, the expert remains both vigilant and resourceful in challenging their own assumptions and developing new understandings and insights.

3.2. Problem-Solving Process

LXD emphasizes the importance of *human-centered* considerations for diverse learners' needs, such as dynamic, flexible, multiple pathways to learn. It also calls for a *goal-oriented* design (e.g., a design that accounts for the nuances of individual motivations and values as they align with the learning and contextual goals). This design approach requires that designers see a diverse range of factors around learners and learning, the sociocultural and technical contexts, and socially mediated meaning making process. Designers must articulate the relationships and connections between these factors, as well as define and organize this knowledge in ways that can be drawn when appropriate. Mental representation of the problem space and information is crucial in connecting relevant evidence and resources to generate solutions. Expert knowledge consisting of both abstract knowledge as well as personal experience (Ellis & Levy, 2010; Ertmer et al., 2008; Rowland, 1992; Stepich, 1991) plays an important role in cognitively organizing problem knowledge for effective and efficient design process (Bransford et al., 2000; Chi et al., 1981; Glaser & Chi, 1988; Stepich & Ertmer, 2009). The difference in how novices and experts organize and structure their knowledge has implications for the process by which they solve learning design problems.

Novice designers lack a clear understanding of the problem and they process the problem and related information less effectively. Novices see only the superficial layers of a problem, seem to mentally represent problems as mere summaries of provided information (Rowland, 1992), and create lists of issues in no particular order, relations, or coherence with each other or the problem itself (Ertmer & Stepich, 2005). Despite a premature or non-existent understanding of the problem, novices complete problem analysis hastily, commit to rigid solutions early, and are less receptive to change even when new and important insights are introduced (Ertmer & Stepich, 2005; McMahon, 2009; Rowland, 1992).

In the caricature, we see our novice is limited when drawing relevant information to synthesize a comprehensive and cohesive picture of the problem along with how to address it. They are restricted by their own personal experiences. This could lead to incomplete and erroneous understanding of the problem, particularly if their experience carries biases and misconceptions. For example, the novice designer projects their own experience around programming (e.g., boring) to define both the problem itself and the learning audience. Assumptions are plentiful around the types of technologies that their learners will enjoy, the genres in which the content should be delivered, and the mechanisms by which motivation relates to engagement and learning. Consequently, this gives our novice a rather narrow view of the

problem, resulting in an arguably hasty design direction catering to a generalized profile of a learner with insufficient support for human-centered and goal-oriented considerations.

In comparison, experts construct conceptual models of problem spaces as networks of related parts organized deliberately by hierarchy, causality, chronology, and operational priorities (Ertmer & Stepich, 2005; Larken et al., 1980; Rowland, 1992) by matching features of new problems they encounter with their expert knowledge (Bransford et al., 1999; Tawfik et al., 2019; Tawfik et al., 2020). Complex mental representations of the problem space set the foundation for their future problem-solving process (Rowland, 1992) and allow experts to selectively retrieve highly relevant cases with possible solutions (Bransford et al., 1999; Chi et al., 1988; Ericsson & Staszewski, 1989; Glaser, 1999). Consequently, by investing more time in defining and refining the problem, experts find solutions faster and solutions are more effective (Chi et al., 1981).

In our expert caricature, the designer is able to process and structure the problem in a substantially richer manner. The designer relies on their mental repository of highly organized knowledge, by referring to relevant information from external resources when necessary. Guided by principles and heuristics accumulated over time, our expert makes reasoned connections to possible learner goals, motivations, and values. By exploring the relationships between different principles, concepts, and mechanisms in direct reference to the problem that includes the learner, the expert solution is much more flexible than the novice's and leaves room for learners to take varying pathways and room for the design to evolve as more understanding is gained.

3.3. Solution Generation

Ill-structured problems, such as learning design problems, are by nature without single algorithmic solutions. The LX elements of learning experience, human-centeredness, and goal-orientedness serve as guides in our efforts to navigate the ambiguity. As LX designers generate and process their design problems, they are challenged to contemplate multiple problem features whereby the solutions contribute toward addressing the diverse cognitive and motivational needs of the learners. To that end, the designer must determine how to address, prioritize, and integrate the parts as a cohesive and interdependent system. In LX, design culminates in a product that represents our reasoning of how the LX elements work together.

A solid foundation must be established to generate reasoned solutions. As one might expect, without this foundation, novice designers find generating solutions difficult. Yet despite their underdeveloped problem space, novices hastily jump to solution generation (Rowland, 1992). Without a working conceptualization of the problem, they refer to original materials often, focus on prescribing content and instruction (McMahon, 2009; Rowland, 1992), and produce singular solutions of instructional type. Novices have difficulty managing multi-step paths; they don't consider varying possibilities and when they do are quick to eliminate them (Kerr, 1983; Rowland, 1992; Tracey & Boling, 2014). Further, novices believe solutions to be the end purpose of design instead of as a means to further understand the problem (Lawson, 2012; Tracey & Boling 2014). When novices reach that end they commit to the point of inflexibility and resist changes to solutions even in the face of new information (Ertmer & Stepich, 2005; Rowland, 1992). Novice designers rarely, if at all, engage in testing and iterating their design solution. Novice designers who reactively respond with content-focused, instructional, single solutions will likely fail to address the variety of learners, goals, motivations, and values that are important considerations for human-centered, goal-oriented, learning experiences.

In our novice caricature, we can see how the designer conceptualizes the design as a single, linear, dictated, instructional path for all learners. From content (i.e., coding exercises), to attitudes (i.e., narrative), to motivation (i.e., playful interaction), the designer envisions a series of cyclical tasks for the learner to follow, presumably until the end instructional objectives are reached. While this novice designer does consider learner beliefs and motivations to some degree, the consideration is meager and implementation remains superficial. The resulting design is static with little room for learners to truly find personal meaning and relevance outside what's currently accorded.

Expert designers are cautious and intentional in their progression toward solution development, proceeding only after they're satisfied with their problem-space comprehension (Perez & Emery, 1995). They perceive solutions as a means to

further understand the problem, as opposed to the ends of design (Lawson, 2012; Tracey & Boling, 2014). They use preliminary solutions to identify critical information about the learner and flexibly adapt (Cross, 2007). This has implications for how they address the complex factors and interactions imbued in the human-centered, goal-oriented, learning experience. Iterative in their approach, experts continually integrate new information through multiple design cycles (Perez et al., 1995). This allows them to use new insights to continually develop and enrich support for multiple kinds of learners in relevant, targeted ways.

In the expert narrative, our designer spends a considerable amount of time establishing the foundational base of the design problem in preparation for the design solution. While the low-level specifics of the design are not detailed in this particular story, at a higher level the design strategy (i.e., project-based learning) is employed for a human-centered, goal-oriented, learning experience. Of key importance is how the expert's design approach addresses various considerations and interrelations around the important identified factors and maps them against the larger design structure. This isn't to say that the expert design is flawless. In fact, both designers discover issues with their final implementations. However, in contrast to the novice, the expert uses this as another benchmark for their continued and iterative design work.

4. Conclusion

Learning experience design, defined as designing learning as a human-centered experience that leads to a desired goal, is a complex, ill-structured, problem-solving endeavor (Crismond & Adams, 2012; Cross, 2004; Jonassen, 2008). Conceptually understanding the nature and process of LXD and engaging in the complex design practice poses challenges to the novice designers. LX designers must take a holistic approach to identify diverse interacting factors, opportunities, and constraints that define the problem space, to provide creative solutions to address the dynamically emerging needs of the learners in relation to the learning context (Nelson et al., 1988). To conclude this chapter we provide practical suggestions and reflection questions to support novice designers through the challenges they may encounter.

4.1. Suggestions for Practice

To solve learning problems one needs extensive knowledge and know-how that is not readily available to the novice designer. One particular learning method recommended in ID, cognitive apprenticeships, is predicated on the concept that experts mentally see and think in ways that novices cannot. This underscores the importance of having experts explicitly articulate their perceptions and cognitions for the novice to access (Collins et al., 1989). Through collaboration with senior designers as envisioned in cognitive apprenticeship, novices can model how to generate problems, select and apply appropriate learning principles, test, and evaluate their design solution. As senior designers articulate what they see and how they think through the planning, development, and testing of design, they reveal to the novice the implicit and complex network present in the problem space. This provides opportunities for novices to build their working knowledge of LXD and develop understanding of oneself as a designer. It's important for novices to accumulate understanding not just directly, but vicariously in order to eventually draw from these experiences when faced with new situations (Ertmer et al., 2008; Tawfik et al., 2019). Conscientious effort to reference empirical research to check one's assumptions about the nature and factors underlying the problem can also be helpful.

Another challenge for novice LX designers is mentally organizing and selecting pertinent information when creating design solutions. Without expert knowledge and schema, this process poses challenges in considering the elaborate, multi-faceted nature of the learners. It is recommended that novice designers take time to organize different information (e.g., theories, concepts, principles, heuristics, cases, personal experiences, etc.) in effective, expert ways.

Using tools to visualize their problem definition could be helpful in identifying and connecting underlying features of the problem, finding gaps and misconceptions about the problem space, and drawing relevant principles. In addition, novice designers are encouraged to contextualize information about the problem space into varied, authentic situations so as to produce nuanced, retrievable schemas when the information is granular (i.e., principles, heuristics). When

information is broad (e.g., abstract: theories, concepts; concrete: cases, personal experiences), novices should work to extract the principles or heuristics that define the situation so as to better index their understanding of the problem.

New design situations will introduce variations that challenge our assumptions and expectations. Therefore, it's important for novice LX designers to deliberately test their design solution, revise their problem space based on the evaluation, and iterate the processes of problem redefinition and solution generation. This will allow for gradual understanding of complex problems in LX as well as opportunities to evolve one's own perceptions and attitudes around LXD.

Finally, to become experts in LXD novice designers need to shift from *learning about* design to *learning to be* a designer. This requires deep reflection and questioning on their own assumptions, beliefs, attitudes, and values about learning and design. These personal positions determine the methods designers use (Nelson et al., 1988; Sheehan & Johnson, 2012) and ultimately develop into design skills (Anderson, 1980). We recommend that novice LX designers face the very ideas espoused in this chapter head-on and negotiate what this new perspective means in light of what we already know from past traditions and our prior experiences. Novice designers need to find a unique path that balances their stance on the field with the domain constraints imposed on them.

To incorporate the values embedded in LXD, we invite the novice to reflect on their own internal beliefs, attitudes, and values—to challenge oneself not just to think about what they must do as designers, but what kind of designer they want to become. Tables 1 - 4 summarize the suggestions and reflection questions for novice LX designers in terms of learning experience, human-centered, goal-oriented, and design.

Table 1

Learning Experience: Summary of Suggestions and Reflection Questions for Novice LX Designers

LX Element Challenge	Suggestions for Practice and Development
LEARNING EXPERIENCE In LXD the learning experience that helps learners construct personally meaningful understanding of the learning process, rather than the instructional materials alone, is paramount. Shifting the focus of design may pose challenges in identifying and defining important features of the problem and drawing relevant information to construct solutions.	When defining and representing problem spaces during problem generation, refer to expert knowledge to see problems as experts, seek expert advice and empirical literature.
	In order to support the problem-solving process use tools to externalize and visualize multiple factors and their relationships underlying the problem space.
	To allow efficient and effective retrieval of guiding cases and principles, organize and connect design-problem and relevant information by meaningful characteristics during the problem-solving process.
REFLECTION	

- Recall your past practices of learning design: How did you conceptualize learning experience vs. learning outcomes?
- In reference to the visual stories: How does the story of how you conceptualize learning experience, compare and contrast to those of the novice and expert designer?
- In light of the LXD suggestions: What are the biggest challenges you need to personally address and how would you change the way you conceptualize learning experience in order to support meaningful understanding through design?

Table 2

Human-Centered: Summary of Suggestions and Reflection Questions for Novice LX Designers

LX Element Challenge	Suggestions for Practice and Development
HUMAN-CENTERED LXD supports personally meaningful learning experience emerging through dynamic interactions of multiple factors in relation to the learners' needs. Designing for dynamic, flexible, multiple pathways to learn may pose challenges in defining, organizing, and designing for diverse cognitive and motivational needs of the learners.	As you generate and solve design problems, define and empathize with learners beyond generalizable traits and characteristics.
	When problem-solving, draw design solutions from a wide array of principles contextualized to the needs of the learner and the learning context during the problem-solving process.
REFLECTION - Recall your past practices of learning design: How did you go about understanding the needs of your learners? - In reference to the visual stories: How do the novice and expert empathize with learners and how might you have approached the same situation? - In light of the LXD suggestions: Going forward, in what new ways do you intend to understand learner needs and how do you imagine the subsequent insights might influence your design decisions?	

Table 3

Goal-Oriented: Summary of Suggestions and Reflection Questions for Novice LX Designers

LX Element Challenge	Suggestions for Practice and Development
GOAL-ORIENTED LXD recognizes that learners enter the learning context with personal goals, motivation, and values that might not align directly with the contextual learning goals. Supporting learners' negotiation and adoption	Be mindful of the complex and dynamic interactions that occur between the learner and the context that they are embedded in. As you generate a design

of the contextual goal in relation to personal goals may challenge novice designers. | solution, recognize, define, and design for multiple goals in the learning context.

REFLECTION

- Recall your past practices of learning design: In what ways might your learners' goals have differed from the learning (i.e., lesson) goals you established and why?
- In reference to the visual stories: How does the novice and expert differ in the way they define their respective design goals and how do you think each goal influenced the ensuing design strategy?
- In light of LXD suggestions: How will you define and conceptualize the goals of the learner and how might you negotiate possible tensions that can arise in relation to contextual goals?

Table 4

Design: Summary of Suggestions and Reflection Questions for Novice LX Designers

LX Element Challenge	Suggestions for Practice and Development
DESIGN In LXD, the role of designers is to provide flexible and dynamic learning contexts and resources that allow multiple learning experiences. Novice designers are challenged in conceptualizing the interaction amongst the multiple problem features as an interdependent system, due to their limited knowledge and past experiences which inevitably carries their assumptions and biases.	When generating design problems test your underlying assumptions and add sophistication to the design solution through cycles of iteration.

REFLECTION

- Recall your past practices of learning design: In what ways might your learners' goals have differed from the learning (i.e., lesson) goals you established and why?
- In reference to the visual stories: How does the novice and expert differ in the way they define their respective design goals and how do you think each goal influenced the ensuing design strategy?
- In light of LXD suggestions: How will you define and conceptualize the goals of the learner and how might you negotiate possible tensions that can arise in relation to contextual goals?

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The Role of Needs Assessment to Validate Contextual Factors Related to User Experience Design Practices

Jill E. Stefaniak & Justin Sentz

Instructional Design   User Experience Design   Contextual analysis   Needs Analysis   Needs Assessment

This chapter will address how instructional designers can validate user needs and contextual factors influencing performance within their user experience design to ensure the transfer of learning to real-world contexts. It will also demonstrate how information gathered from needs assessments can be leveraged to identify and develop the necessary scaffolds to optimize the user experience. While contextual analysis aims at understanding the user's work practice, needs assessment delves into identifying, classifying, and validating the needs of users as they pertain to their work practice. It is imperative that an instructional designer fully understands the intricacies and nuances of the application setting/environment to design a prototype that addresses specific contextual factors that may support or inhibit the transfer of learning into that environment. Instructional designers trained to engage in needs assessment that incorporates context into the design of the user experience will be better positioned to facilitate transfer from the learning space to the work practice space. The chapter proposes a framework to assist designers with leveraging outputs of the needs assessment to the user experience design so that contextual factors can inform the entire experience from project conception to transfer of knowledge to real-world applications.

1. Introduction

Instructional designers are called to make decisions at various times throughout a project. These decisions may include, but are not limited to, selecting the type of instructional delivery system, identifying evaluative metrics to assess learning, and the types of instructional strategies warranted for teaching the subject matter (Kenny et al., 2005; Sugar, 2014). One can thus argue that the goal of any instructional design project, regardless of its scope, is to facilitate learning and improve performance. To achieve these two overarching goals using technology, instructional designers must address the user experience. User experience design is the process of designing products that are relevant to the everyday experiences of users or learners (Goodman et al., 2012; Lallemand et al., 2015).

Emphasis is placed on the user throughout the entire design process to address issues with relevancy, fidelity, usability, and functionality (Norman, 2013; Sanders, 2002). User experience design encompasses the ability for a designer to address all the ways a learner (hereinafter referred to as the user) will interact with the product (intervention) being developed. This mindset goes beyond addressing the instructional environment and extends to include how the user

will transfer their learning to a real-world environment (Lallemand et al., 2015; MacDonald, 2019; Rosenzweig, 2015). This requires the instructional designer to dissect the user experience into a variety of layers to ensure a successful transfer. To be successful, instructional designers must expand their design practices to include the instructional products they will design as well as acknowledging and taking into consideration the factors that may support or hinder the delivery of their intervention. Instructional designers can leverage a lot of useful information that will inform their decisions related to user experience design that can be yielded from completing a needs assessment to identify an appropriate infrastructure.

2. Background

The instructional design process requires instructional designers to undertake a number of different analyses in order to gather sufficient data that will inform their designs. These analyses often include needs assessment and needs analysis; contextual analysis; and learner analysis. The purpose of a needs assessment is to identify the gap between the current state of performance and the desired state of performance (Altschuld & Kumar, 2010; Kaufman & Christensen, 2019). Needs analysis is the process of further investigating the performance gap and determining what is contributing to the gap. It is important that an individual facilitating a needs assessment also integrates analysis to better understand the situated environment (Watkins & Guerra, 2002; Watkins & Kaufman, 1996). This puts them in a position to validate the needs that have been presented by their organization or clients. While these are mutually exclusive, a comprehensive needs assessment will include contextual and learner (or audience) analysis.

A needs assessment is recognized as being an important component of the instructional design process (Branch & Dousay, 2015; Dick et al., 2009; Morrison et al., 2012; Smith & Ragan, 2005); however, it often tends to be minimized to focus more on learner analysis. The goal of every needs assessment is to successfully identify the performance gap and propose viable solutions, either instructional or non-instructional, to achieve the desired performance results. Conducting a needs assessment helps the instructional designer illuminate contextual factors that need to be considered while bridging the gap between current and desired results (Burton & Merrill, 1991; Watkins et al., 1998; Witkin & Altschuld, 1995). These factors may include organizational politics, other training interventions that are being implemented simultaneously, employees' perceptions, and resources available to support new learning initiatives.

Most instructional designers find themselves being presented with the needs of a project when they initially meet with their clients (Stefaniak, 2018). Oftentimes, they are expected to address these needs at face value and begin designing their solutions. Typically, these needs are more aligned with what the instructional design field would refer to as a learner analysis. Learner analysis is focused on gathering a sufficient amount of data on a learning audience to design effective instruction. While this information is important, it is also necessary for the instructional designer to gather data on other elements within the system that may be contributing to or hindering learner performance. Needs assessment extends a further reach on assessing the environment that comprises learner analysis and user analysis data, as well as capturing data about other elements or factors within a system that may impact the learner (Tessmer, 1991).

Contextual analysis is the process of analyzing factors that may contribute to or inhibit knowledge acquisition and transfer of learning (Tessmer & Richey, 1997). While several seminal papers have been written in the instructional design field recognizing the impact that contextual analysis poses for the learning experience (Tessmer, 1991; Tessmer & Harris, 1990; Tessmer & Richey, 1997), very few studies have been conducted exploring this reach on the instructional design process. Baaki and Tracey (2019) noted that their survey of instructional design studies that focused on context yielded a total of 31 studies; many of which relied on different interpretations of the term "context". A majority of these studies were focused on the learner context (e.g., Giamellaro, 2014; Son & Goldstone, 2009). Other studies focused on design contexts (Gibbons, 2011) or learning activities and experiences in context (Rivet & Krajcik, 2008; Robinson & Dearmon, 2013).

In general, the studies published on context report one aspect of letting setting as it relates to the instructional experience, as opposed to exploring how instructional designers leverage contextual factors from the beginning of a

project to the end. Tessmer and Wedman (1995) attributed this to the limitation that the instructional design models commonly referenced in our field are not contextually-sensitive. While this criticism is 25 years old, this continues to be a concern raised by scholars in the field (Gibbons et al., 2014; Kinuthia, 2009). This may be due, in part, because the majority of instructional design research is focused on the instructional processes and products. While needs assessment is mentioned in a number of the instructional models referenced by the field (Branch & Dousay, 2015), there is a lack of emphasis on the use of needs assessment to examine systemic nuances of the environment that impacts instruction. Contextual factors need to be examined more deeply in a needs assessment and then aligned throughout the instructional design process.

This chapter will emphasize the role of needs assessment as instructional designers validate contextual factors in their user experience design practices. When trained to engage in needs assessment, instructional designers will be better positioned to facilitate transfer from the learning space to the work practice space by taking a systems view of their design practices. Needs assessment expands beyond the scope of the immediate instructional unit or event being designed and can be leveraged to enhance what the instructional designer knows about their learning audience.

We begin this chapter by exploring the application and interpretation of user experiences in design practices. We then present a systems approach to user experience (UX) design practices, differentiate between needs assessment and contextual analysis as they relate to UX design, and discuss the intersection between instructional design decisions and UX practices to facilitate the transfer of learning. We conclude this chapter by offering a framework to help instructional designers utilize needs assessment techniques to validate contextual factors that may implicate their user experience design practices.

3. Applying and Interpreting User Experience in Design Practices

While the term UX design has only recently been adopted in the instructional design field, it has been used for quite some time in areas such as human factors and human-computer interaction. Similar to terms such as design thinking or evaluative thinking, the concept of UX design can (and should be) treated like more of a mindset rather than a specific method (Gray, 2016). Battarbee and Koskinen (2005) contend that there are three traditional approaches to applying and interpreting user experience in design: measurement, empathetic, and pragmatism. The approach that relies on measurement is primarily involved with testing the emotional reactions of users and improving the experience as a result. The empathetic approach, on the other hand, is centered on providing an experience that addresses the perceived needs or aspirations of the user. The third approach involving pragmatism takes a more cognitive view of user experience, as the meaning of the experience itself is continually constructed by the user while interacting with the environment. The authors contend that these three approaches rely too heavily on emotions and the individual user experience, and they propose an approach involving co-experience whereby the emphasis is placed upon user experience as it emerges through social interaction.

A needs assessment can provide a mechanism to validate contextual factors, especially the social aspects of the instructional and transfer environments, and provide supporting data to better understand how the situated creation of meaning is leveraged in user design practices. The field of instructional design is experiencing a shift in placing greater emphasis on better understanding the learner. In recent years, we have begun to see a transition in instructional design research to focus more on empathetic design (Parrish, 2006; Tracey & Hutchinson, 2019; Vann, 2017). This attention to employing a more empathetic approach to instructional design tasks instructional designers with taking a more learner-centered approach to the design process by gathering information that provides a more personal and holistic overview of the learner as a person (Matthews et al., 2017; Parrish, 2006; Rapanta & Catoni, 2013).

This approach therefore places more emphasis on UX strategies early in the design process. Additional time is allocated at the beginning of a project to develop a comprehensive understanding of the learner (user) audience. Designers spend time gathering data from multiple sources to better understand how their audience will interact with the design, how they will interpret information presented by the design, and how the design is used in real-world

settings. The use of personas is an example of a strategy that has been used and reported in the instructional design literature to capture a more thorough depiction of learning audiences (Johnston, 2011).

4. A Systems Approach to UX Design

Instructional design as a field has been greatly influenced by general systems theory, which considers learning environments to be both systematic and systemic (Churchman, 1965). The learning system is thus dependent upon the interaction of its parts, as well as the broader context in which that system exists. Hall and Fagen (1975) defined a system as consisting of "a set of objects together with relationships between the objects and between their attributes" (p. 52). Systems theory in education was initially influenced by the study of biological systems and then relating those processes to machines (von Bertalanffy, 1972). Closed systems are those whose components are isolated from others within the larger system, while open systems involve components that interact with each other.

Along with situated learning theory (Brown et al., 1989), general systems theory has led instructional designers to consider problem-solving within the context of broader social environments. Within an open learning system, the interaction between components will likely result in changes within the individual components (including the learners themselves). While it may be tempting to categorize a particular learning environment as "closed" to avoid the challenges arising from the complexity of open systems, von Bertalanffy (1972) warned that a failure to address the interactivity of components presents an unrealistic view of the true environment. For this reason, instructional designers must conduct a true contextual analysis to uncover the interactivity that exists within the larger system to create instructional solutions that are situated within the larger environment.

To implement the co-experience approach to user experience design proposed by Battarbee and Koskinen (2005), instructional designers must understand the learning system and larger environment in which users socially interact to create meaning from their experiences. Forlizzi and Ford (2000) proposed that user experiences are an ever-changing product of the interaction that takes place between the user, objects, other individuals, and the environment as a whole. The instructional designer must acknowledge the interactivity taking place within the learning and transfer systems to design solutions that are situated in the social environment of the user. While this necessarily poses challenges related to the continuous emerging behaviors affecting interactivity within the environment, instructional designers need to strategically bind their system to constrain the design space and make it more manageable for a particular project. This process begins during the needs analysis through the collection of relevant contextual information, and it continues as the designer builds upon prior experience and offloads cognitive demand through the use of decision-making strategies to address those contextual factors within the newly bound system.

5. Needs Analysis and Contextual Analysis in User Experience Design

Contextual design is referenced in UX design and human-computer interaction literature. It provides a means to collect data about users in the field, interpret that data, and use it to create prototype products and concepts that will be used by users (Holtzblatt & Beyer, 2013). "In Contextual Design, the term *work practice* refers to the complex and detailed set of behaviors, attitudes, goals, and intents that characterize a set of users in a particular environment" (Holtzblatt & Beyer, 2013, 8.1.1 Principle section). It is imperative that a designer fully understands the intricacies and nuances of the work practice environment so that they can design a prototype that addresses particular contextual factors that may support or inhibit the transfer of learning into the work practice environment.

Holtzblatt and Beyer (2013) characterize contextual analysis in user design as adhering to the following principles: a) systematic design must support and extend users' work practice, b) people are experts at what they do- but are unable to articulate their work practice, c) good design requires partnership and participation with users, d) good design is systemic, and e) design depends on explicit representations.

While contextual analysis aims at understanding the user's work practice, needs assessment further delves into identifying, classifying, and validating the needs of users as they pertain to their work practice. Training instructional designers on aligning needs assessment with UX design practitioners offers several advantages to the design process. It positions the instructional designer to approach a situation with a systems view (Stefaniak, 2018, 2019). If performed correctly, data derived from a needs assessment can serve as benchmark data for evaluating performance outcomes associated with design prototypes.

Data derived from a needs assessment can guide the instructional designer on how to impose boundaries on their design practices (Stefaniak, 2019). The instructional designer can narrow the scope of their design by fixating on specific contextual factors that have an immediate impact on the system. Recognizing gaps existing between the current state and desired state of affairs can inform the design of instructional scaffolding needed to support the transfer of knowledge from the learning space to the work practice. Lastly, it provides a mechanism to assist the designer with validating the needs of the users; thus contributing to a smoother and more accurate transition to the desired learning and performance state.

6. Decisions to Facilitate Transfer From the Learning Environment to Real-World Setting

According to Jonassen (2000), the type of decision-making that takes place within activities such as design is inherently connected to ill-structured, complex problem-solving. These types of problems involve a large number of decisions throughout a series of design project phases (Jonassen, 2008). Some processes of decision-making can be classified as normative, whereby an instructional designer would choose an optimal solution for a particular situation based on theoretical reasoning and the application of best practices within the field. On the other hand, naturalistic decision-making involves the designer being influenced by emotions or interests they may not even be aware of during the process. Jonassen (2012) explains that decisions are not only affected by previous experience but are also "often made or influenced by unconscious drives and emotions" (p. 343). Much as user experience design acknowledges that users are influenced by their emotions, aspirations, and interactions with the environment, instructional design identifies these factors as influencing designers while they engage in decision-making. Because research shows decision-making within the instructional design to be an iterative process (Jonassen, 2008, 2012), instructional designers must continually rely on the contextual factors examined during the needs assessment to take into account the needs and motivations of both themselves and the users within the learning environment.

In his foundational study of strategies to promote the transfer of statistics problem-solving, Paas (1992) found that cognitive load was reduced and transfer performance was enhanced through the use of worked example problems during the learning phase. He concluded that the use of this strategy directed the learner's attention to tasks most relevant to the goals of the problem and prevented the learner from generating, and later remembering, erroneous solutions to a problem. When the instructional designer considers the contextual factors likely encountered in the transfer environment through a needs assessment, the task-related goals (and also the likely distractions) within the transfer context will be represented optimally within the instructional context. This results in both increased effectiveness and efficiency of learning through user experience design approaches that emphasize increased opportunities for problem-solving practice and enhancement of practice through problem variability representative of the transfer context.

Concerning variability during the learning phase, Paas and van Merriënboer (1994) discovered that users who encountered high variability of worked examples experienced less cognitive load and superior transfer performance within the domain of problem-solving in geometry. The users spent less time during the learning phase working with the material, and they experienced less mental demand during transfer as a result of this user experience design approach. To generate a realistic set of worked examples that can be used to present a high degree of problem variability to the learner, the instructional designer must first validate the contextual factors that lead to variability within the work practice space. Through a needs analysis, the instructional designer can determine the optimal structuring of worked

examples to reduce extraneous load, anticipate how learners will reference the examples during problem-solving, and identify the contextual factors that will motivate the user to transfer their learning to the work environment.

Jelsma and van Merriënboer (1989) found that, in their study of learners performing cursor movement tasks, those who trained using a randomized practice schedule improved their task completion time and made significantly fewer errors during transfer performance than those who trained using a blocked practice schedule with problems containing similar surface characteristics. They observed that learners perform better when presented with a series of randomized tasks that contain high contextual interference, which fosters their ability to work with variations of the task likely to be encountered in the work environment. During the needs analysis, examination of the transfer context is crucial to identify the various environmental factors that are likely to fluctuate and change the surface characteristics of problems that the user will need to solve during transfer. As with other aspects of user experience design, these ever-changing contextual factors can be related to various objects, other users, the environment as a whole, and even the users themselves as they interact with the system.

7. A Framework to Validate Contextual Factors in User Experience Design Practices

To help instructional designers fully consider contextual factors that may influence the whole user design experience from the conception of a project to application and transfer of knowledge in the real-world setting, we offer a framework to assist with leveraging needs assessment outcomes to the UX design space (Figure 1). Similar to the bookends of a needs assessment, our framework depicts the current user state and the desired user state.
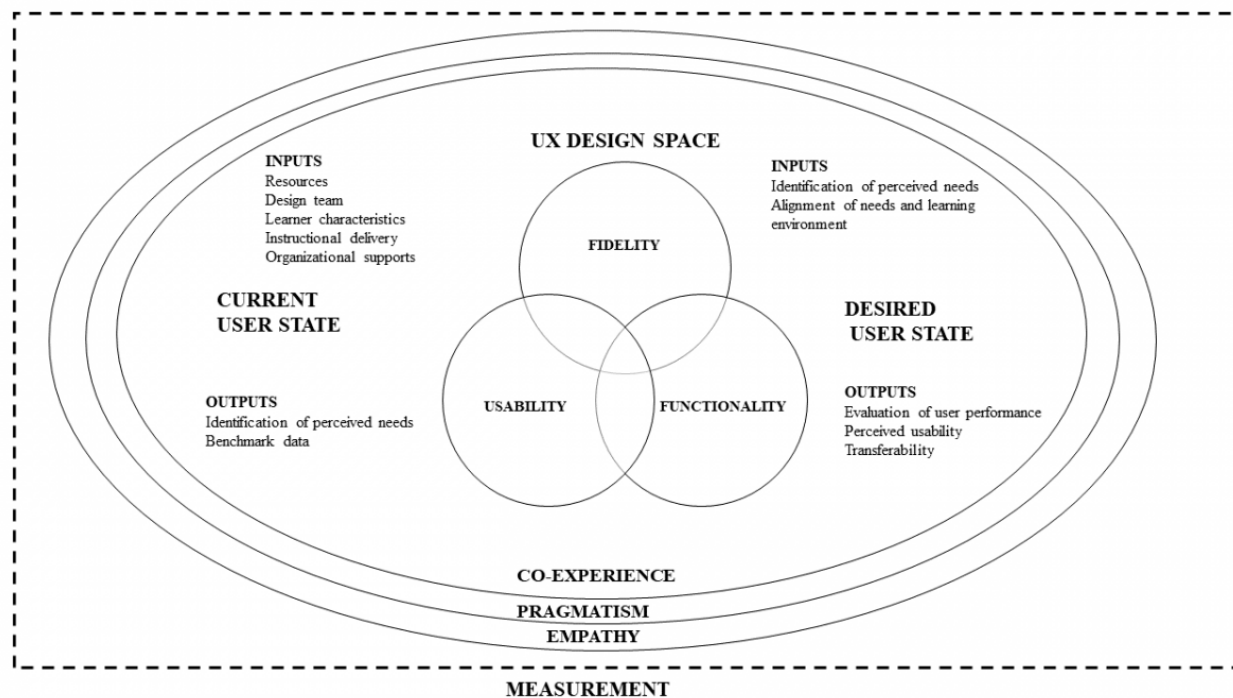
Figure 1

A Framework to Validate Contextual Factors in User Experience Design Practices

The current user state identifies inputs that contribute to the needs assessment process. Examples of these inputs include resources allocated to the project, design team personnel, known learner characteristics, available instructional delivery mechanisms, and organizational supports that are currently present. A direct output of the current user state is the identification of perceived needs. Throughout the needs assessment process, the instructional designer is responsible for gathering sufficient data to validate that the identified needs are actual needs (Stefaniak, 2018). The

data gathered during the needs assessment can be referred to later in the project life cycle to benchmark the results in the desired state against data collected during the current state.

To bridge the gap between the current and desired states, the instructional designer must consider the perceived needs, actual needs, and desired needs. The solutions in the UX design space must demonstrate alignment between these needs. The designer needs to refer to data yielded from the initial gathering of data to inform their design decisions. All UX design solutions must take into consideration the fidelity, usability, and functionality (Norman, 2013) of the intervention (solution) to ensure the transfer of learning to the application setting to meet the desired user state.

To determine whether the desired user state has been met, the needs identified during the initial phase of the needs assessment must be supported by sufficient data and aligned with the learning environment designed in the UX design space. The outputs identified in the desired user state include evaluating the user's performance and ability to transfer knowledge in the application setting. This transference is assessed according to the (a) perceived utility of the UX intervention as it relates to the real-world environment, (b) the degree of fidelity as it relates to transferring skills acquired through the presentation of the UX intervention, and (c) the identified supports to promote the sustained application in the environment. The outputs of the desired user state are then benchmarked against the results gathered during the current user state to determine the validation of the needs and success of the transfer.

The entire process in Figure 1 is enclosed by three bands: empathy, pragmatism, and co-existence to demonstrate that they are applied to the entire life cycle of the project. These bands represent two of the three approaches to applying and interpreting user experience in design identified by Battarbee and Koskinen (2005). The empathic band comprises the need for demonstrating empathy of the user throughout all phases of the project. During this time, the instructional designer needs to be considering the perceived, identified, and anticipated needs of the user to design a solution that can be transferred to the application setting. This empathetic approach is ubiquitous in the UX design workspace as the instructional designer (a) tests for functionality of their design, (b) conducts assessments to measure usability, and (c) works to create high fidelity interventions that minimize challenges when applied to the real-world setting.

The pragmatic band recognizes cognitive aspects related to the user's experience transferring knowledge from the learning environment to the application setting. This approach encompasses the user's ability to understand the intervention, apply it, and perceive its usefulness. This band recognizes the importance of the instructional designer to provide an opportunity for the user to make meaning of the experience by directly interacting with the environment. This aligns with the need to address functionality and fidelity in the UX design space and supports the need for a systems approach to UX design.

Building upon Battarbee and Koskinen's (2005) suggestion that UX design practices need to facilitate a co-experience whereby the emphasis is placed upon the user experience as it emerges through social interaction, our third band involves co-existence. By integrating opportunities that promote social experience within the UX design space and learning environment, the instructional designer is better equipped to ensure a seamless transfer to the application setting as well as validate user needs pertaining to the project.

One of the three traditional approaches to UX design noted by Battarbee and Koskinen (2005) includes measurement. This approach is focused on gathering data to measure the reactions of the user to improve the experience. Our framework has placed greater emphasis on measurement throughout the entire project lifecycle by demonstrating that it oversees and guides the entire needs assessment, UX design, learning, and transfer processes. Throughout the entire lifecycle of a project, the instructional designer should gather data to (a) verify and validate needs; (b) anticipate user needs that may present in the application setting; and (c) evaluate the successful transfer in terms of fidelity, functionality, and usability.

To best implement this framework, we offer the following heuristics to guide instructional designers as they utilize this framework to validate contextual factors in user experience design practices through a needs assessment.

1. *Verify the users' needs*. While almost every instructional design project will begin with a client presenting their perceived needs for the project, the instructional designer must verify those needs to design an effective user experience. To address functionality, usability, and fidelity of the UX experience, it is important that these constructs are aligned with the users' actual and anticipated needs and not solely on the perceived needs. This can be accomplished by developing a better understanding of the users' current experiences and identifying their desired state of performance.

2. *Gather data from multiple sources*. When verifying the users' needs, the instructional designer must gather data from multiple sources to sufficiently verify the need. Gathering data from multiple sources to verify each need enables the instructional designer to triangulate data and strengthen their argument for their proposed design interventions. The use of multiple data sources also assists with identifying patterns of performance and any factors that may enhance or hinder the design experience, both in the learning environment and the application setting.

3. *Gain an understanding of how the user will apply knowledge in the application or transfer setting*. The UX experience involves the instructional designer testing their intervention in terms of functionality, usability, and fidelity (Norman, 2013). Gathering data to help form an understanding of how the user will apply knowledge in the application setting will assist the instructional designer with achieving positive metrics in terms of these three constructs, as well as gaining a clear understanding of the user's desired state of performance. Information gathered during this phase of a project will help the instructional designer minimize the gap between the learning experience and the application setting.

4. *Determine gaps that may exist between the learning experience and the application setting*. The instructional designer needs to determine any gaps that may exist between the learning experience and the application setting. Addressing these gaps helps the instructional designer contend with the realities of the project and the users' experiences, which enables them to design an intervention that is realistic and accurate. During the design phase of the project, the instructional designer should practice an iterative approach to user design, carefully aligning and checking that each instructional strategy and decision aligns with meeting the needs of the users. These gaps can be mitigated by employing an empathetic and pragmatic design philosophy to support the users' construction of meaning through social interactions and experiences with the actual environment.

5. *Identify what infrastructure is needed to support the transfer of knowledge*. The process of needs assessment tasks the instructional designer with dissecting the environment (or situation) from a variety of levels. Oftentimes, data is gathered to understand the user's responsibilities and needs, processes related to performance, and organizational mechanisms that have been put in place to support performance. Identifying the non-instructional interventions needed to support performance is just as important as designing the learning interventions. These interventions may include (a) designing learning management systems, (b) developing job aids to support performance in-situ, (c) establishing protocols for implementing training and monitoring completion, and (d) addressing organizational development such as job descriptions, departmental functions, and responsibilities. These non-instructional interventions must be identified, explained, and established when the learning intervention is presented to the user in order to support transfer to the application setting.

6. *Mitigate challenges with transferability by providing just-in-time supports*. By validating the contextual factors that may impact UX design practices, the instructional designer is better equipped to (a) measure the degree that the desired user state of performance has been reached, (b) ascertain the non-instructional interventions needed to sustain the transfer of knowledge, and (c) identify users' specific challenges and anticipated needs regarding transferability. This data can be leveraged to assist the instructional designer with mitigating challenges associated with transferability by providing just-in-time supports. These supports may include just-in-time training, job aids, organizational processes, and repositories of information to assist users upon completion of learning activities.

8. Conclusion

The topics of UX and needs assessment can significantly benefit the instructional design experience by helping instructional designers take a data-driven, empathetic, and pragmatic approach to aligning instructional interventions to users' actual and anticipated performance needs. Our field continues to talk about challenges associated with ensuring the transfer of learning and what that means for design practices. The goal of this chapter is to explore how the validation of needs and contextual factors influencing performance can be accounted for in user design to ensure the transference of learning in real-world contexts. It also demonstrates how information gathered from needs assessment can be leveraged to identify and develop the necessary scaffolds to manage the user (learner) experience.

As the instructional design field focuses on ways that UX design practices can (and should) be woven throughout the instructional process to gain a deeper perspective of the learner and the utility of their designs (Earnshaw et al., 2018), additional research is needed about the impact of contextual factors and UX design. Furthermore, there is a need for the field to share examples of how this can be employed in different contexts. Also needed is the use of design cases that dissect how particular UX design strategies are utilized to gather learner data and thus inform the entire design process.

This chapter offers a framework for using needs assessment to validate contextual factors in user experience design practices. We intend to help instructional designers leverage data gathered during needs assessments to employ empathy and pragmatism in user-centered learning interventions. By embracing a systems view of the users' environment, the instructional designer is better positioned to mitigate the gap between the users' current state and desired state of performance. It also provides initial data to measure the degree to which improvement performance has been achieved, and the identification of the necessary organizational resources warranted to support application in the transfer setting.

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The Design Implementation Framework: Guiding Principles for the Redesign of a Reading Comprehension Intelligent Tutoring System

Kathryn S. McCarthy, Micah Watanabe, & Danielle S. McNamara

Intelligent Tutoring   Reading Comprehension   Cognitive Walk-through   Experimental Evaluation

The Design Implementation Framework, or DIF, is a design approach that evaluates learner and user experience at multiple points in the development of intelligent tutoring systems. In this chapter, we explore how DIF was used to make system modifications to iSTART, a game-based intelligent tutoring system for reading comprehension. Using DIF as a guide, we conducted internal testing, focus groups, and usability walk-throughs to develop iSTART-3, the latest iteration of iSTART. In addition to these evaluations, DIF highlights the need for experimental evaluation. With this in mind, we describe an experimental evaluation of iSTART-3 as compared to its predecessor, iSTART-ME2. Analyses revealed an interesting tension between system usability and user preference that has important implications for instructional designers.

1. Introduction

Intelligent tutoring systems, or ITSs, provide the opportunity for individualized computer-based instruction, evaluation, and feedback at scale. ITSs are effective learning tools—students who engage with ITSs show learning gains similar to one-on-one human tutoring or small group instruction (Ma et al., 2014; VanLehn, 2011). Advances in technology and pedagogy mean that ITSs are constantly evolving to be "better, faster, and cheaper" (Craig et al., 2018). Thus, iterative modifications are a critical aspect of ITS development. These modifications should not only be theory-driven and empirically-validated, but also practically-valuable for a variety of stakeholders (Craig, 2018; Roscoe et al., 2017). While meaningful educational gains are the key outcome for ITSs, other aspects of the ITS experience are also important to acknowledge. However, little work has been published on usability and experience in intelligent tutoring systems (Chughtai et al., 2015; Lin et al., 2014). The Design Implementation Framework (DIF; Stone et al., 2018) was developed to address this gap in ITS design and user experience.

In this chapter, we outline DIF and describe key aspects of the framework in the context of foundational design approaches, such as ADDIE. We then present a case study in which we used the DIF in the redesign of the reading comprehension ITS iSTART. Guided by principles of DIF, we conducted participatory research that included teachers and students throughout the development process and an iterative development, implementation, and evaluation cycle. The result of this effort is an improved system that is not only more accessible but also more engaging and effective.

2. Design Implementation Framework

DIF (Stone et al., 2018) is an emerging framework for instructional designers that connects research, design, and implementation processes. DIF is a cycle composed of five phases: (a) Defining and Evaluating the Problem, (b) Ideation, (c) Design and User Experience, (d) Experimental Evaluations, and (e) Feedback and Implementation (Table 1).

DIF is founded upon existing methods of instructional design—such as the Analysis, Design, Development, Implementation, Evaluation model (ADDIE; Molenda, 2003) and Design-based Implementation Research (DBIR; Fishman et al., 2013)—but was developed with specific consideration of the affordances and constraints of intelligent tutoring systems. Further, DIF is a design approach that takes into consideration a variety of end users. For example, teachers play an important role in the success of educational technology in the classroom, yet instructors are often ignored as both facilitators and end-users (Stone et al., 2018). DIF is part of a larger effort by researchers in education, cognitive psychology, and the learning sciences that encourages participatory design and educators-as-partners in the development and refinement of educational technologies (Luckin & Cukurova, 2019).

Table 1

Phases of the Design Implementation Framework

Note: Adapted from Stone et al. (2018).

DIF Phase	Description
Defining and Evaluating the Problem	Identifying one or more central research questions or problems emerging from the developers' instructional or theoretical goals.
Ideation	A creative and collaborative brainstorming process to generate a variety of plans for implementation or further investigation.
Design and User Experience	Usability and user experience research methods to test and refine the designs (e.g., sketches, mockups, paper prototyping, and wire framing).
Experimental Evaluations	Evaluation of new hard-coded interface and fully-functional system features to assess impact on learning, motivation, and other outcomes of interest via laboratory or school-based experiments.
Feedback and Implementation	Deployment of the technology in authentic learning settings (e.g., classrooms).

DIF differs from design sequences such as ADDIE and DBIR, both in terms of specific phases of development and the structure of those phases. For example, a quick Google search for ADDIE yields diagrams that generally fall into one of two layouts. The first (Figure 1) indicates a unidirectional loop, starting with analysis and ending with evaluation. The second (Figure 1) indicates a loop including the first four aspects, with evaluation at the center, presumably to reflect its impact at each stage of development.
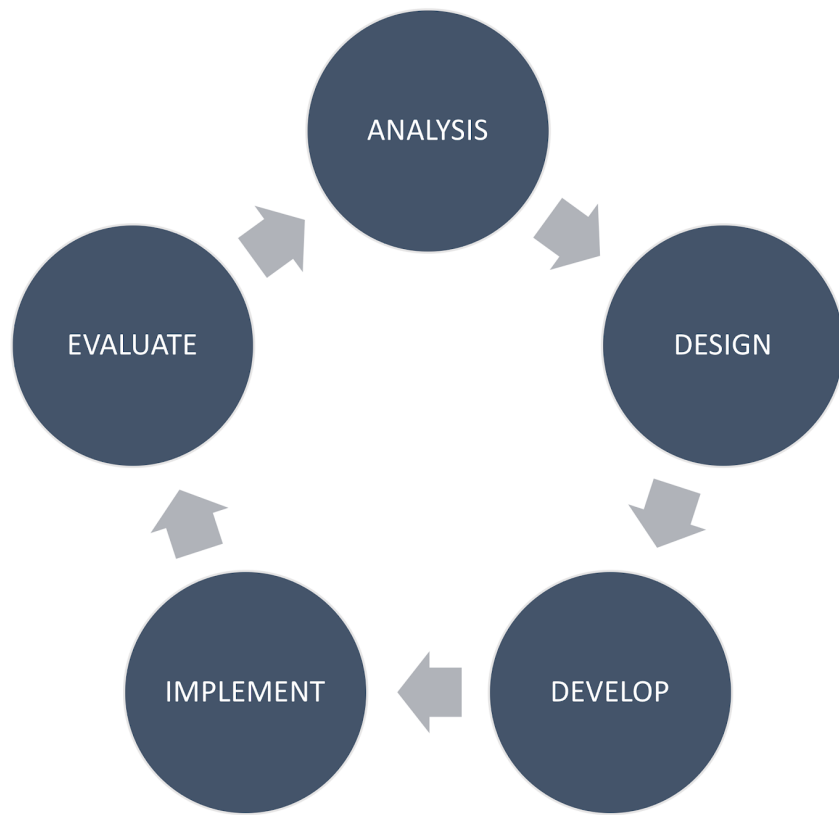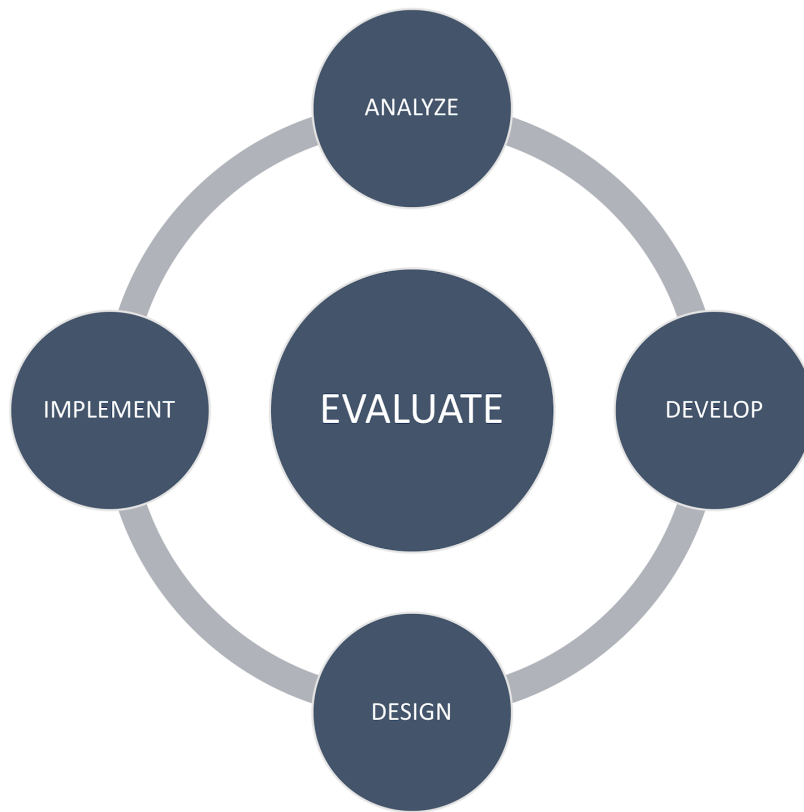
Figure 1

Common Diagrams of ADDIE Model
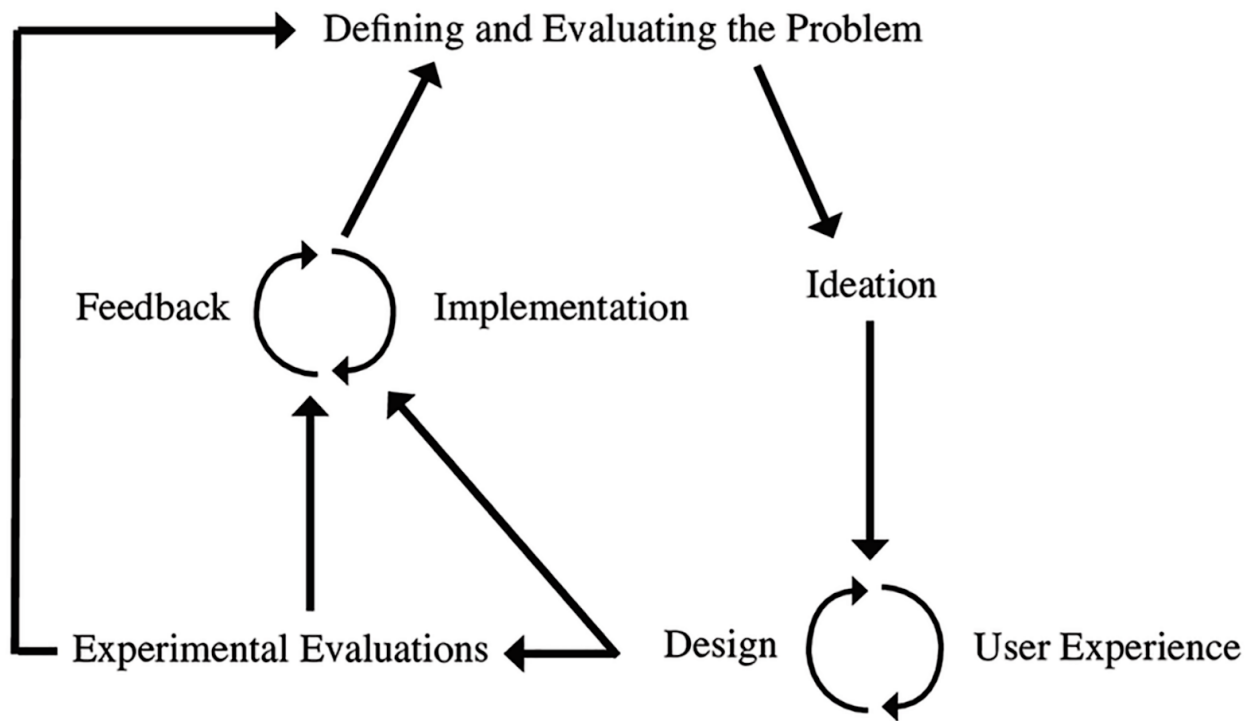
Figure 2

The Design Implementation Framework

Note: From Stone et al. (2018).

In contrast, DIF is conceptualized with feedback and evaluation at various points along iterative refinement (Figure 2). This complexity reflects the diverse and potentially conflicting outcomes relevant to successful ITSs. ITSs must first and foremost support learning, but other aspects of design can help or hinder learning gains. Craig and colleagues (2004) demonstrated that boredom during ITS use is negatively correlated with learning. A pedagogically-motivated system modification might demonstrate increased learning in short lab trials; if the users find the system boring, they may not learn as much or engage with it long enough for tutoring to have substantial long-term effects (Jackson & McNamara, 2011, 2013). Alternatively, designers might introduce new features to increase and maintain interest. However, if these features are distracting, they can cause learners to engage in unproductive, off-task behaviors that do not support learning (Rowe et al., 2009). Good ITS design requires finding a "sweet spot" of a system that is easy to use, enjoyable, and efficacious. Thus, a key element of the DIF cycle is experimental evaluations in addition to user feedback.

For example, we recently tested the effect of two metacognitive prompts (McCarthy et al., 2018). We were motivated by research in both reading comprehension and ITS development showing that increasing metacognitive awareness can improve learning (Azevedo et al., 2016; Snow, 2002). We developed and designed two types of metacognitive prompts to help students better monitor their performance. We implemented these two prompts into a beta-test classroom within our ITS, iSTART (described below), and compared the effects of the prompts (independently and in combination) to the version of iSTART without these features. In a sample of more than 100 students, we found that the addition of these prompts did not lead to learning gains above and beyond the original iSTART practice environment architecture. Critically, the prompts also lead to decreased performance during system use, especially for less-skilled readers (McCarthy et al., 2018). Based on these findings, these metacognitive prompts were not implemented as default options into iSTART.

Experiments allow researchers to provide strong evidence that the changes made to the system have meaningful impacts on a variety of dimensions (e.g., motivation, perceptions, time-on-task, learning) prior to full implementation. By

conducting evaluations incrementally and across various dimensions, we can continuously monitor the balance between differential outcomes in order to improve the system in ways that are both user-friendly and impactful.

3. Case Study: iSTART

In the remainder of the chapter, we describe how DIF was used to guide additional iterations of redesign of our ITS, iSTART. Interactive Strategy Training for Active Reading and Thinking (iSTART) is an intelligent tutoring system that uses video lessons, guided instruction, and game-based practice to improve students' reading comprehension skills through self-explanation training. Self-explanation, or the act of explaining a text to yourself during reading, has been shown to be an effective learning strategy across a variety of domains (Bisra et al., 2018; Chi, 2000). Further, instruction on how to produce high quality self-explanations during reading improves students' comprehension of complex scientific texts (McNamara, 2004, 2017). iSTART leverages natural language processing to provide automated self-explanation instruction and feedback to improve reading comprehension skill.

In iSTART, students are introduced to five self-explanation strategies: comprehension monitoring, paraphrasing, predicting, bridging, and elaborating. These strategies have been shown to improve comprehension across a variety of age ranges and skill levels (e.g., Cain & Oakhill, 1999, 2006, 2011; McNamara et al., 2006; Palincsar & Brown, 1984). The strategies are introduced in brief video lessons and then students are introduced to a practice environment. In Coached Practice, students practice reading texts and writing their own self-explanations. Natural language processing-based algorithms guide both summative and formative feedback. A summative score from 0-3 is presented on the overall quality (i.e., *poor*, *fair*, *good*, or *great*) of the self-explanation. Formative feedback is provided by a pedagogical agent who offers targeted feedback messages to help students revise their self-explanations.

Students can also play generative games or identification games. In the generative games, students earn points for writing higher quality self-explanations. In the identification games, students read example self-explanations and earn points for identifying which strategy is being demonstrated. These points can then be used to purchase more game play or to purchase accessories for the player's avatar.

The iSTART system has undergone several iterations. The original iSTART (McNamara et al., 2004) was a computer-based version of the in-person intervention, Self-Explanation Reading Training (SERT; McNamara, 2004). iSTART included video lessons and guided practice with feedback. iSTART-2 (Levinstein et al., 2007) improved the self-explanation scoring and feedback algorithm and used classroom-based data to make improvements to the existing modules. iSTART-ME (Motivationally-Enhanced; Jackson et al., 2009; Jackson & McNamara, 2013) introduced the game-based practice environment. While the games themselves do not improve comprehension, they improve students' motivation, which, in turn, mediates their learning gains and continued training (Jackson & McNamara, 2011, 2013). iSTART-ME was updated to iSTART-ME2 in order to incorporate a teacher interface. This required reprogramming the system using a combination of Java and Flash (Snow et al., 2016). Each of these versions were built based on design research between our research team, teacher-partners, and student participants. Building on this tradition of redesign and reevaluation, we set out to use DIF to develop the next generation of iSTART reading comprehension training.

3.1. Defining and Evaluating the Problem

The first phase of DIF requires designers to define and evaluate the problem. To identify issues that were most relevant to our end users, we iteratively worked with teachers and students to identify weaknesses in the existing version of the system, iSTART, and the barriers that might prevent teachers from using iSTART effectively. We conducted focus groups and worked closely with teacher-partners who were implementing iSTART (in this case, iSTART-ME2) into their classrooms. We surveyed students from these classes as well as users from our lab-based studies. These experiences revealed three aspects of iSTART in need of redesign.

The first major concern we heard from our teacher-partners was that the existing iSTART system could only be run on desktop or laptop computers. As mobile technology has become more affordable, tablets have become more prevalent in classrooms (Burke & Hughes, 2018). Many of our teacher-partners had ready access to tablets, whereas they would

need to reserve space in computer labs in order to use iSTART during the school day. We also took into consideration that students from lower socio-economic status homes tend to rely on smartphones and tablets for connectivity (Li et al., 2015; Tsetsi & Rains, 2017). Thus, some students have restricted access to engaging in additional practice at home. The solution to this problem was relatively direct. By recoding iSTART from Flash to HTML5, we were able to offer responsive design (e.g., mobile compatibility). Although this was a straightforward change, the actual recoding of the system required extensive effort on the part of the programmers and designers (as well as federal funding from the Office of Naval Research and the Institute of Education Sciences).

A second problem identified was that teachers and students found the overall graphics and design of iSTART to be outdated. This was not too surprising as the system was developed in the early 2000s and only superficial aesthetic changes had been made in the interim. Users also noted that they disliked the cold, text-to-speech narration used in the training videos and suggested using real voices. This feedback was not new—teachers and students had previously complained about the automated speech engines (Levinstein et al., 2007). At that time, the automated voices were not replaced because key aspects of iSTART were still under development. We had relied on automated voices so that these revisions could be made relatively quickly without needing to re-record and re-edit the content as iterative changes were being implemented and evaluated. Since that time, the content of the lessons has concretized. Thus, the ability to use recorded voices was now more practical.

The third and final problem identified during the problem definition phase was that the teacher interface introduced in iSTART-ME2 was difficult to navigate. One benefit of iSTART's text-general algorithm is that instructors can import their own texts to tailor lessons to specific classes or students. However, our teacher-partners found importing and assigning texts to be cumbersome. Teachers who struggle to make the ITS work quickly and easily are not likely to integrate tutoring into their class time. Even the best-designed learner tool may cease to have an impact if the instructor does not integrate its use into the classroom. The teachers also noted that the student progress and performance pages provided useful data, but that it would be beneficial to have these data aggregated in meaningful ways that could help them to diagnose issues more quickly.

3.2. Modernizing the Look of iSTART

With the problems defined, we moved to the next phases of DIF: ideation and design. We began ideation by informally examining trends in website and game design. The research team met to discuss which designs were most appropriate for iSTART. As we moved into the design phase, the research team met weekly to discuss and develop potential designs. Individual team members presented mockups of the interface or particular game elements, and the team iteratively compared designs and offered feedback. By having multiple potential designs, the team was able to compare and contrast these options. As we progressed, these discussions led to a single design that "mixed and matched" the best aspects of the different designs. These design discussions led us to replace the cartoon icons with photographs to represent the various strategies and redesigned the games to have more realistic looks and feel. The fonts, tabs, and buttons were modernized accordingly (Figure 3). We updated the training videos to be consistent with the overall interface design. Once we were satisfied with our mockup designs, we shared them with our teacher-partners. They reacted positively toward the new interface and expressed that their students would like the new design and videos. We used this feedback to move more confidently into implementation.

To address concerns over the narration, we elected to record human narrators. The team considered theoretical and practical constraints when determining the sounds of our narrator(s). Ultimately, we decided on two male voices and a female voice. We decided on multiple narrators for several reasons. We first considered theoretical implications— research indicates that the gender of an instructor (or pedagogical agent) can impact students' perceptions and learning (Baylor & Kim, 2004; Elias & Loomis, 2004) and that these effects are driven by whether the instructors' gender is the same or different from that of the learner (Krämer et al., 2016). Including different "instructors" of differing genders allowed us to reduce potential bias. The second reason was more practical. Having multiple voices facilitates adding in other voices if content needs to be edited or added, and, if new videos are added in the future, without the need to entirely re-record old versions to maintain consistency.

Figure 3a

Previous iSTART Training Menu and the Redesigned HTML5 iSTART-3 Training Menu
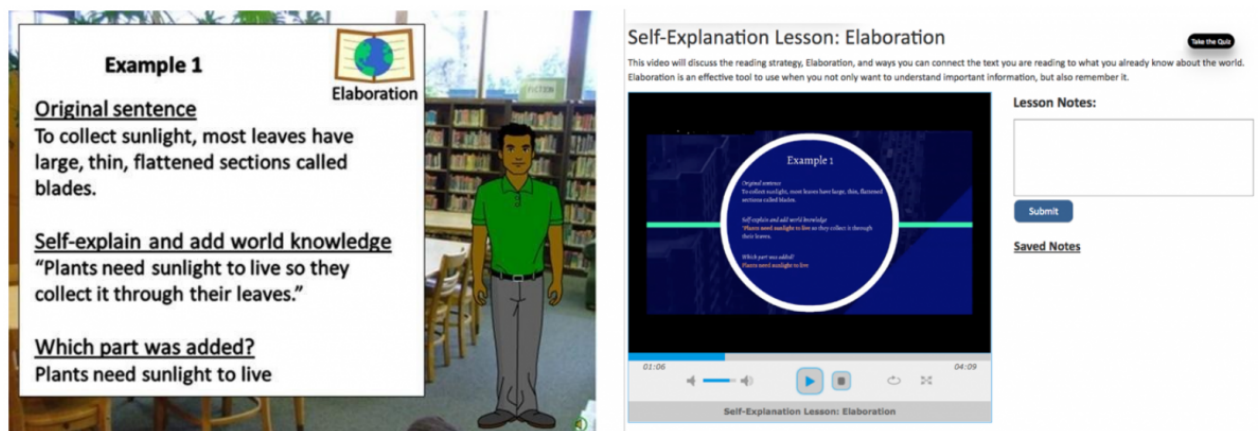

Figure 3b

Previous iSTART Video and the Redesigned HTML5 iSTART-3 Video Interface

Figure 3c

Previous iSTART Practice Game and the Redesigned HTML5 iSTART-3 Practice Game

3.3. Improving the Teacher Interface

In parallel with the modernization of the system, we also began ideation for redesign of the teacher interface. The teacher interface includes two broad categories of information. The first is a calendar-based screen on which instructors can assign texts and modify deadlines. The second is a dashboard on which instructors can view student progress in terms of overall completion of videos and assignments as well as in terms of aggregate and individual self-explanation scores.

We conducted several focus groups and interviews with teachers who were using iSTART as well as teachers using its sister ITS, The Writing Pal (Roscoe et al., 2014), with the intent of developing these interfaces in parallel, with slight modifications for the specific needs of each system. These interviews helped us to define the specific aspects of the interface in need of redesign as well as to allow the teachers to join us in ideation. In order to gather user experience data, we constructed prototypes of the interface using the Marvel prototyping app. Prototyping apps and programs allow designers to generate interactive mockups in order to rapidly complete multiple cycles of design and experience prior to investing time and effort into hard coding the system. We adapted a cognitive walkthrough methodology (Lewis et al., 1990; Wharton et al., 1994) to collect user experience data. Cognitive walkthrough is a usability inspection method in which evaluators (e.g., developers, research participants) are asked to go through the system as if they were a user in order to identify weaknesses in design and functionality of a system. In most cases, evaluators are given a series of tasks that a user might need to complete. Evaluators talk-aloud about their process (e.g., Ericsson & Simon, 1998; Pressley & Afflerbach, 1995) as they complete these tasks, and their system behaviors are recorded and analyzed. We conducted two rounds of cognitive walkthroughs and redesign. This cycle helped us to simplify navigation and to better understand how users were interpreting the student performance data. We used what we learned from those experiences, as well as advances in dashboard design (e.g., Few, 2006), to drive the changes specific to the iSTART teacher interface. For example, in iSTART-ME2, lesson progress was displayed numerically. In iSTART-3, students' progress is represented through color-coded progress bars (Figure 4). Teachers can also view class-level data on a particular assignment or drill down to see individual student scores presented in a simple line graph.

LAST NAME	FIRST NAME	Overview			Monitoring			Prediction			
		Completed	Checkpoint Score	Frequency	Completed	Checkpoint Score	Frequency	Completed	Checkpoint Score	Frequency	Complete
		1		1	1	3	1	1	4	1	1
		1		1	2	2.5	2	1	4	1	1
		1		1	1	4	1	1	4	1	1
		1		1	1	4	1	1	4	1	1
		1		1	1	4	1	1	3	1	1
		1		1	1	4	1	1	3	1	1
		1		1	0		1	1	2	1	1
		1		1	1	3	1	1	1	1	1
		1		1	0		2	0		1	0
		1		1	1	4	1	1	4	1	1
		1		1	1	4	1	1	4	1	1

Student ID		First Name	Last Name	Lesson Progress		Practice Texts			Stair Stepper			
				Percent complete of all lesson videos	Percent correct on checkpoint questions	Average self-explanation score (max=3.0)	# of texts completed	Total trophies	Average Comprehension Multiple-Choice Score (max=100%)	# of texts completed	Current Text Difficulty Level (max=12)	
				38%	0.58	0.00	0	0	0%	0		
				38%	0.5	2.11	1	1	0%	0		
				44%	0.75	0.00	0	0	0%	0		
				11%	0.37	0.00	0	0	0%	0		
				50%	0.85	2.57	1	1	0%	0		
				44%	0.53	0.00	0	0	0%	0		
				77%	0.52	1.50	1	1	0%	0		
				38%	0.35	0.00	0	0	0%	0		
				44%	0.57	0.00	0	0	0%	0		
				16%	0.87	0.00	0	0	0%	0		

Figure 4

Teacher Interface from iSTART-ME2 and the Redesigned HTML5 iSTART-3

As we neared full implementation, we realized that these new visualizations could also benefit student users. Consistent with the DIF, we took the opportunity to redefine our problem to include the need for clearer data visualization for both teacher and student. Thus, the student progress screen was recoded with an identical colored-coded progress bar design and the ability to open these aggregate scores into game-level or text-level metrics.

3.4. Implementation and Feedback

After these rounds of design and user experience with the prototype, we hard-coded iSTART to reflect these design changes. After this implementation, we collected feedback for this phase by conducting a final cognitive walkthrough with the hard-coded system. We asked undergraduates (n = 5) to complete a series of target tasks that teachers and students would need to complete. The intent of this walkthrough was to emulate the needs of a teacher implementing iSTART in the classroom. The teacher would need to be able to quickly add new texts and assignments and to view student progress, but they would also need to be familiar with navigating the larger system to help guide students and troubleshoot when necessary. We used screen capture software to record system behavior (e.g., assigning a text to a class, playing a game, finding their average score on that game in the progress screen). One limitation in prompting thinking aloud is that it can potentially disrupt the natural cognitive processes that occur or encourage participants to engage in processes that would not have occurred without verbalizing (Branch, 2000; Nisbett & Wilson, 1977). Rather than asking participants to think-aloud, we conducted retrospective interviews to gain additional insights into user experience. In retrospective interviews, users are asked after the task to talk about what they did during the task. Although this approach has some limitations including potential bias or simple memory errors, we elected to use this less invasive method. Retrospective interviews also allow the researchers to ask additional follow-up questions to clarify or expand upon the user's responses. Data from the retrospective interviews indicated that the system was relatively easy to navigate, but that some of the tabs were labeled in ways that were unclear, leading to some confusion. For example, the majority of students had difficulty finding their average self-explanation score with the tab labeled "Texts Scores." In design, we had given this tab this shorter name so that the length of each tab was consistent. However, users preferred clarity of a tab's function over consistency of design. The users suggested in their interviews that the label "Self-Explanation Scores" would be clearer. The researchers involved in these walkthroughs brought these findings back to the research team and modifications were recommended to our programmers.

3.5. Experimental Evaluation

Experimental evaluation is a unique and critical aspect of DIF. Experiments, unlike other research methods, allow us to draw causal conclusions. True experiments (as opposed to quasi-experiments) require that users are randomly assigned to either the treatment or a comparison (i.e., "control") group. In experiments, the goal is to hold all other variables constant, so that the only difference across groups is the variable of interest (or the manipulation). For example, in the aforementioned study by Baylor and Kim (2004), the researchers used the exact same audio for their pedagogical agents and changed only the agents' appearance (e.g., race). By holding the audio constant, the researchers were able to more confidently conclude that learners' perceptions were based solely on appearance rather than other characteristics or behaviors. The ability to make direct comparisons is important for interpretive feedback. For example, a user rating of 3.75/5 might seem like an excellent score on its own. However, a comparison is necessary to contextualize any particular score. That is, if the previous version of the system was rated on average as 4/5, then a score of 3.75 may not be considered as high as it appears on the surface. Experimental evaluations can be a bit more time and resource intensive, but they can provide instructional designers greater confidence in the efficacy of their tools.

Guided by DIF, we conducted an experimental study to evaluate user perceptions of iSTART-3—the version of the system that includes responsive design, modernized aesthetics, and clearer dashboards. In some of our previous work, we conducted large-scale (n > 100), long-term experiments (e.g., more than 10 hours of system use; semester long implementations). While these approaches are certainly valuable and allow the opportunity to explore interactions with individual differences (see Jackson & McNamara, 2011; McCarthy et al., 2018), we also encourage designers to consider employing smaller-scale experimental designs with convenience samples. Such evaluations afford strong

empirical evidence of efficacy without being cost or resource prohibitive. Indeed, this sort of repeated testing at increasingly larger scales is well-aligned with the focus of the DIF.

These cognitive walkthroughs had primarily focused on teachers as the end users. Within this cycle of system modifications, our next step was to focus on evaluating iSTART from the perspective of students as the end users. For this round of evaluation, we conducted a smaller scale study with a convenience sample of undergraduates. Undergraduates (n = 54) interacted with iSTART for about 3 hours. Three hours was enough time to complete the video lessons, as well as to have time to play a variety of practice games. The undergraduates were randomly assigned to work with iSTART in the new responsive design (iSTART-3) version or the previous version (iSTART-ME2). After interacting with the system, they responded to the questions presented in Table 2 using a 1 to 5 Likert scale. The control condition, iSTART-ME2, allowed us to directly compare how our design changes compared to the previous iteration.

Table 2
Average Likert Scale Ratings as a Function of iSTART Version

	iSTART-ME2 (n = 29)	iSTART-3 (n = 25)		
	M (SD)	M (SD)	t(52)	p
Training Videos				
I enjoyed the overall look and feel of the training videos.	2.90 (1.24)	3.52 (.87)	2.11	0.040
The narration used in the videos was easy to understand.	3.03 (1.40)	4.08 (.76)	3.33	0.002
I felt like I learned the material during today's session.	3.10 (1.11)	3.80 (.87)	2.54	0.014
Practice Games				
I enjoyed the overall look and feel of the practice games.	3.11 (1.32)	3.19 (1.30)	0.24	0.812
The games were enjoyable to play.	3.21 (1.34)	3.27 (1.08)	0.17	0.870
Overall Interface				
I enjoyed the overall look and feel of the iSTART interface	2.96 (1.29)	3.04 (.91)	0.24	0.810
When I wanted to know how well I was doing in iSTART, the information was easy to interpret	3.57 (1.23)	4.00 (1.10)	2.25	0.029

As shown in Table 2, there was little difference across versions in students' perceptions of the overall environment or the practice games. However, participants preferred the new look of the training videos and found the narration easier to understand. Participants who used the new version of iSTART also found it easier to interpret the data that was presented about their performance. These results suggest that our redesign of iSTART addressed end-user feedback about the system.

We also had students complete a usability survey, adapted from the System Usability Scale (Brooke, 1996). This 10-item measure can be administered and scored quickly and the survey items are written to be system general. That is, the SUS items do not need to be modified from tool to tool. Perhaps due to its ease of use, the SUS has been used thousands of times and has been demonstrated to be a robust tool (Bangor et al., 2008). Thus, the SUS is a low-cost, relatively high-impact tool for instructional designers.

Students responded to the 10 items about the usability of the system on a Likert scale from 1-7. Although the test can be administered on paper, we used the survey system, Qualtrics, to collect the self-reported SUS. The students' usability rating for iSTART-ME2 (M = 34.9, SD = 8.68) was marginally higher than the ratings from iSTART-3 (M = 30.3, SD = 10.3), t(49) = -1.75, p = .09. One potential explanation for this lack of difference is that iSTART-3 was essentially in its infancy. As such, we discovered bugs in the system that were less about design and more about growing pains of the system. For example, one participant noted that the lesson video suffered from an excessive lag time in responsiveness. Additionally, our experimenter observational notes indicate that some students were logged out of the system during practice and needed to log back in, which would be disruptive and understandably frustrating. In sum, our findings indicated that the new iSTART-3 interface showed significant improvements in aesthetics and interpretability of performance data as compared to iSTART-ME2, but that the new system was not more user-friendly and, if anything, was slightly less usable than its predecessor. Our findings from this experimental evaluation highlight the tension between different critical outcomes in ITS design and redevelopment. Thus, designers need to carefully examine how modifications influence a variety of factors related to system use. We are using these data to address potential bugs, but also to modify the system to be more usable, while monitoring that these changes do not have detrimental effects on learning.

Our next steps, guided by DIF, are to test iSTART-3 in authentic classrooms and collect feedback from both teachers and students. This level of evaluation will complete one full "cycle" of the Design Implementation Framework, but will provide the data necessary to guide problem definition in the next DIF cycle for iSTART.

4. Conclusions and Lessons Learned

In this chapter, we introduced the Design Implementation Framework and demonstrated how DIF guided improvements in the intelligent tutoring system (ITS) for reading comprehension, iSTART. The development of iSTART has been an iterative process that has resulted in several versions (Levinstein et al., 2007; McNamara et al., 2004; Snow et al., 2016) that reflect the state-of-the-art at the time they were created. By leveraging DIF, we have been able to integrate new technologies, such as mobile compatibility, while maintaining a system that is effective in terms of learning gains and that meets the needs and ever-changing demands of its end users. Data from cognitive walkthroughs and experimental evaluations showed positive effects of our redesign efforts. More specifically, iSTART-3 improved students' perceptions of the ease of use and enjoyment of the training modules (which were modified), but did not affect students' perceptions of the games (which were updated, but not modified). It is expected that iSTART will require further updates to meet the expectations of users and maximize the availability of iSTART as the standards for and capabilities of educational technology evolve.

This implementation of the DIF gave us a means of improving our ITS, iSTART, but it also gave us valuable insight into the framework itself. Although other frameworks (e.g., ADDIE, DBIR) do not preclude rapid cycling, DIF's emphasis on feedback cycles within the larger design cycle encouraged us to continually test our ideas and modifications at each phase of development. The explicit inclusion of experimental evaluations also allowed us to uncover the inconsistency across system usability and user preference. One limitation to the present work is that we explored only self-reported preference and usability. To more fully understand different components of learner and user experience, future testing will be conducted to collect behavioral data as well as target learning outcomes.

Perhaps the most important lesson learned from our team, through the two decades of development with iSTART, is that usability and experience must be gauged across a series of iterative cycles of design, feedback, and evaluation. As DIF highlights, evaluation can take a variety of forms and should occur at multiple phases of design. DIF encourages user-centered design at all stages of the ITS life cycle. Notably, our users ranged from members of the research team, to lab-based participants, to classroom students, and to teachers. We encourage developing instructional designers to consider a variety of methods of evaluation, such as cognitive walkthroughs, short-term experimental comparisons, and longitudinal studies. DIF's emphasis on multiple types of evaluation should encourage instructional designers to consider multiple end users as well as the many different types of outcomes that are relevant to high-quality intelligent tutoring systems. DIF has served us well in development (and redevelopment) of iSTART and its sister system, The

Writing Pal (see Stone et al., 2018). We anticipate that this approach to design will be beneficial for additional ITSs and other educational technologies. However, conducting more research with the framework will be critical before generalizations can be made.

Those who are interested in developing educational technologies, and more specifically ITSs, should be driven by considerations of learning processes and performance gains. That is, the foundations of any quality system should be built upon sound learning theory. This focus on effective instruction, practice, and feedback inherently defines the development of systems that help students learn. However, instructional designers must also recognize the need to focus on usability and user experience. Solely examining learning gains or whether a student enjoys engaging with a system is not enough. Both learning and motivation are important considerations in the development and implementation of educational technologies. Equally crucial is the consideration of how educational technologies differentially impact different types of learners. The ultimate objective in the use of automated tutoring systems is to adapt to the needs of the users. As such, examining the effects of individual differences and adapting to those differences should remain a key priority.

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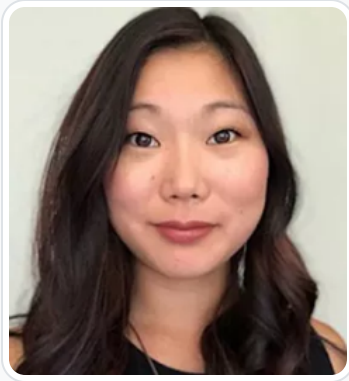
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From Engagement to User Experience: A Theoretical Perspective Towards Immersive Learning

Danielle Oprean & Bimal Balakrishnan

Engagement   User Experience   Learning Experience   Immersive Technology

As we see immersive technology becoming ever more prominent in education, from our mobile devices to highly immersive virtual reality headsets, there is a growing need to look beyond existing, pragmatic conceptualizations of the technology. We need to explore immersive technology from a theoretical perspective focused on the user and learner experience for it to make meaningful contributions to education. The way we experience technology often frames how we engage with it and determines whether we continue to use it. Immersive technology is often conceptualized based on the affordances provided to the user without any associations made back to theoretical underpinnings drawn from user experience and learning experience research. The authors take known conceptualizations of user experience and immersive technology and link them to the learning experience to form a working theoretical framework that can help develop an understanding of learner engagement with this emerging technology. We begin with concepts related to immersive technology, then build a theoretical framework and conclude with implications for learning approaches through examples from the spatial disciplines.

1. Introduction

Immersive technology is becoming more affordable, leading to increases in adoption for education, particularly in the spatial disciplines (Klippel et al., 2019). This increase in adoption necessitates that we look beyond existing conceptualizations to a more theoretical perspective of the user and learner experience. Our perceptions of technology often frame how we continue or discontinue engaging with it. Immersive technology places the user or learner in the center of the activity and provides an experience from a first-person perspective. Immersive technology takes the form of one of three types: virtual reality (VR), augmented reality (AR), and mixed reality. However, our understanding of experiences resulting from immersive technology use often differs based on the discipline. Therefore, we focus our efforts on a single discipline first—the spatial disciplines where design and spatial relationships are central to the use of immersive technology.

Currently, there are two broad perspectives towards immersive technology in learning; one is focused on learning effectiveness, and the other is focused on user experience (UX) from human-computer interaction (HCI). Both perspectives depend on engaging users or learners through technology. The learning effectiveness perspective emphasizes the benefits of immersive technology and examines whether learning occurs or not. The gap lies in

underestimating any downsides to immersive technology by focusing on hypothesized benefits without sufficient empirical backing. From a strictly UX perspective, learning is ill-defined, making it harder to validate if learning occurred. The UX perspective primarily focuses on achieving *presence* or *embodiment* as a way to gauge the success of immersive technology. As a result, much of the research investigating such technology tends to incorporate aspects from both but only at a conceptual level with no consideration for how they work together or how engagement does or does not occur.

With the rapidly changing nature of immersive technology, it has been challenging to formalize a singular theoretical framework that addresses discrepancies between both perspectives and their relationship towards engagement. It is particularly difficult when the focus is on the technology—the factor that constantly changes. For instance, positive results from a study using Google Glass, an older AR technology, may not necessarily hold true when repeated with a phone-based AR. While both can be conceptualized as AR technologies, their technology affordances are different. Similar issues can be found when referring to technology such as the CAVE or any head-mounted display such as Oculus Rift. Rather than using a black-box approach (i.e., treating technology as monolithic entities) to understand the connection between UX and learning experiences through immersive technology, we look at various technologies through the lens of affordances adopting a variable-centered approach proposed by Nass and Mason (1990). Looking at commonalities across the technology, in the form of various affordances, provides an easier way to now compare and understand technology in a way that stands the test of time and emergence of new technologies. This approach helps us address the challenge of formalizing a singular theoretical framework for immersive technology and learning. We illustrate this framework through work in the spatial disciplines.

Like other fields, the spatial disciplines such as architecture, geography, and geology increasingly use immersive technology based on the promise of several benefits from the experience of the *virtual place* (Bricken, 1990; Dalgarno & Lee, 2010). Such technology affords learners the ability to visit the ocean floor, the cells of the human body, or any location not possible or not easy to visit in real life (Dalgarno & Lee, 2010). Other benefits include reducing distractions commonly found in real-world learning experiences (e.g., weather, crowds, etc.; Robinson, 2009), providing multiple perspectives (Soto, 2013), and increasing engagement through activity (Procter, 2012). Depending on the type of technology and intended experience, these benefits are perceived to be widespread. However, for a systematic investigation of these technologies, we have to begin by defining what we term as immersive.

Immersion is a function of the technology that forms an experience—technological attributes or affordances as opposed to the individual perceptions of the experience (Slater, 1999). Immersion encompasses technical components that involve a user's senses (e.g., visual, audio, tactile, etc.). Technologies considered to be immersive often refers to a variety of technology that profoundly differs in functionality yet provides the same primary visual, auditory, and other sensory experiences. The differences between these technologies (AR to VR for instance) vary in terms of the degree of immersion provided or the number and form of technical attributes that enable the technology to be considered immersive. Additionally, such technology differs in how it involves the senses; AR utilizes the real world and enhances what already exists whereas VR uses a completely synthetic space creating only the sensory information necessary for experiencing that space. For more on the role of space as a catalyst in shaping the immersive experience in AR, VR, and MR, see Milgram and Kishino (1994). In our short introduction here, we provide a simplified table of immersive technology types and the technical and spatial attributes generally used for visual immersion, the most common and easily identifiable form of immersion (Table 1). For more on technical attributes of immersion, see LaViola, Kruijff, McMahan, Bowman, and Poupyrev (2017).

Table 1

Technology Type Attributes of Visual Immersion

Type	Description	Examples	Technical Attributes	Spatial Consideration

Augmented Reality (AR)	Enhances the real-world with information.	• Phone-based (QR Code) • Meta View Headset	• Field of view limited to the viewing angle of a phone/tablet/headset • No field of regard (no peripheral vision) • Level of detail (limited to phone/tablet processors)	• Enhances the real world with visual information	Reality
Mixed Reality (MR)	Moves between the real and virtual place.	• HoloLens • Windows MR Headset	• Field of view limited to the viewing angle of a headset • No field of regard (no peripheral vision) • Level of detail (limited to headset computing processor)	• Replaces items in the real world with visual information • Ability to move between the real world and the synthetic (e.g., real-world to 3D models)	to
Virtual Reality (VR)	Provides an entirely synthetic experience.	• Oculus Rift • Oculus GO • HTC Vive • CAVE • Google Cardboard	• Field of view limited to the viewing angle of a headset or screens/monitors used • Field of regard that includes the peripheral vision • Level of detail (limited to processors of computer/headset)	• Presents a synthetic world with various types of visuals (e.g., 360° images, 3D models, etc.)	Virtual

We also further clarify what we mean by immersive technology in the context of VR. From Google Cardboard to HTC Vive to Oculus Rift and many other technologies on the market, immersion is one differentiating factor from other forms of technology. Early adoption of VR in education took the form of desktop monitor-based environments referred to as Virtual Worlds, where learners control avatars to participate in learning activities within a synthetic environment (Dede, 2009; Nelson & Erlandson, 2012). Newer technology, however, provides capabilities afforded by immersion, such as field of regard (displays that include the user's peripheral vision) or wider fields of view (a wider viewing angle).

Additionally, immersion is accompanied by some form of interactive capability (Bowman & McMahan, 2007). Immersive technology allows students to view and interact with synthetic environments and objects in three-dimensional space (Piovesan et al., 2012). We limit the focus of our theoretical framework to immersive technologies, though our framework can be applied to less immersive technology to a certain degree. This focus avoids confusion with desktop-monitor technologies and avatar-based platforms such as Virtual Worlds (Nelson & Erlandson, 2012) which are focused on social interaction and communication rather than the technology that involves a user's perceptual senses. After clarifying the concept of immersion and introducing the various technology types, we now focus our attention to the other key concept in our discussion—learner engagement.

Learner engagement is an outcome often associated with immersive technology (Dede, 2009). Stemming from a broader concept of engagement, placing focus on the learner aligns better with educational outcomes. Our focus on learner engagement, therefore, is based on an established relationship between the use of a technical intervention and learning outcomes (Meggs et al., 2012) and research data showing sustained use and focus on a learning tool can improve learning outcomes (Dede, 2009). Our framework presents two ways in which the sustained experience can potentially lead to improved outcomes through engagement-focused attention on the learning content and through association with the real world using spatial relationships (a demonstrated way for how learners understand and apply knowledge in real-world situations).

We present a framework, the *immersive framework*, describing the role of UX in immersive technology and how it leads to learning, drawing from a variable-centered approach towards technology affordances. We then illustrate this framework utilizing concepts specific to immersive technology and its use in education within the spatial disciplines. This chapter continues with a description of key concepts related to immersive technology, UX, and learning. We discuss the immersive framework and the implications of its use in the context of learning. We conclude with the intended impact on engagement within learning scenarios that use immersive technology and how the immersive framework can be applied in other disciplines.

2. Conceptual Framework

To tackle developing a framework for immersive learning, we address both the UX and usability conceptualizations of the technology to ultimately lead to learner engagement, our framework's outcome. We present our conceptualization of learner engagement followed by key UX factors from user experience and usability. User experience has been at the forefront of HCI to determine the overall value of ideas such as aesthetics, affect, and fun (Hassenzahl & Tractinsky, 2006). We distinguished it from usability as necessary for continued engagement with technology. Specifically, usability focuses on the task, looking to efficiency and learnability of particular technology as a matter of performance. Conventional conceptualizations of usability include effectiveness, efficiency, and satisfaction (Monk et al., 2002). While effectiveness and efficiency are related to the user's ability to accomplish a task through technology, satisfaction presents a different perspective. User satisfaction encompasses many aspects that focus on a user's judgment of whether a technology meets particular needs and relates to learner engagement through motivation.

UX in the context of immersive technology additionally focuses on specific factors meant to involve users in the experience, ultimately improving and sustaining satisfaction, a differentiating factor between immersive and non-immersive technology. Newer technology offers first-person, ego-centric experiences that utilize physical user movement (e.g., head-turning, walking, etc.) and provide a sense of embodiment not possible through desktop monitors. Embodiment, in turn, improves the overall experience by acknowledging a sense of control over the interaction (e.g., the user must move their own body to interact). This control leads to improved affect or enjoyment of the experience, which are directly related to learner engagement (D'Mello et al., 2017). We focus on key factors relating to how users experience immersive technology, including presence, embodiment, enjoyment, and novelty.

2.1. Learner Engagement

Meaningful engagement is fundamental to the learning process (Martin, 2012) as a key component of active learning (Chi & Wylie, 2014). Yet, engagement remains a complex concept with multiple definitions (Glas & Pelachaud, 2015). Engagement is often used synonymously with motivation (Martin, 2012), interest, involvement, immersion, and user experience (Lehmann et al., 2012). These other concepts, while related, are not the same. However, they can influence how engagement forms. In education, focusing on the learner often frames how technology engagement is received. For this chapter, we refer to engagement as *learner engagement* and distinguish it from similar concepts of motivation, involvement, immersion, and user experience (inclusive of satisfaction). Continuous interaction with learning content underlies active learning and is essential to maintain sustained engagement (D'Mello et al., 2017). The relationship between engagement and learning outcomes is not straightforward; being engaged does not directly lead to improved learning outcomes but can increase the chances for it. Much of the relationship between engagement and learning

outcomes could be related to other factors including implementation, teaching method, learning content, and even the individual learner through additional factors of motivation, satisfaction, and interest.

2.2. Presence

The concept of *presence* or the feeling of "being there" (Slater & Wilbur, 1997) within a virtual place is central to UX in the context of immersive technology. In the spatial disciplines, we can focus more narrowly on the feeling of "being in a space", commonly referred to as *spatial presence*. See Balakrishnan, Muramoto, and Kalisperis (2007) for a more detailed definition of spatial presence within the context of spatial disciplines. This feeling is highly subjective and dependent on several factors ranging from the content of the virtual place, the overall technology experience, and even the disposition of the user. The mechanism underlying the sense of presence is still not fully understood and therefore makes it one of the most prominent UX concepts explored with regards to immersive technology. Presence occurs most often when attention is focused on the virtual place to block out indicators of the real world and allow the user to feel like the simulated space is real (Wirth et al., 2007).

In the learning community, presence as related to immersive technology has been hypothesized as highly influential and necessary. Despite this belief over the years, its role and contribution to learning are still debated (Makransky et al., 2019; Markowitz et al., 2018). Focusing specifically on spatial presence, we can conceptualize its role in learning design. Presence helps to achieve situatedness, establishing a location and context for learning to occur. The spatial component of presence helps to establish place markers or references between objects and other content through the spatial relationships experienced. This is similar to the real world where aspects of navigation, scale, distance, and organization play a role in how learners understand and remember actions that occur. An example of this would be visiting a new city, where known knowledge of navigation is often used and relearned based on the experience. Presence, from a UX perspective, occurs on a scale and grows and diminishes as the experience continues. This suggests a dependency of presence on other UX factors to extend the experience. As such, there is a need to force continued engagement through variation, much like in active learning.

2.3. Embodiment

Embodiment provides a sense of familiarity by using a user's own body as a frame of reference to participate in an activity (Kilteni et al., 2012). We make a distinction from the term's use to refer to the phenomena experienced when a user embodies the actions of an avatar as his/her own (Dede, 2009). Embodiment occurs when a user can seamlessly interact with the virtual place as if they were using their own body. In newer immersive technology, physical movement is now tracked, enabling a greater sense of embodiment to occur as users can actually walk around a virtual place, stand at their individual height, and even turn their heads to look around.

Through desktop-based virtual worlds, the learning community has capitalized on the role of avatars as a means of embodied learning, to relate actions to an identity a learner assumes (Schultze, 2010). Therefore, little has been done to investigate the role of the actual user's body being involved in the learning experience. The closest form of embodiment as found in immersive technology is the use of field trips and fieldwork, where the learner is physically involved in an activity and limited by his/her bodily limitations. For example, geology students learn about the slope and scale of rock faces by actually standing next to them or climbing on them because they can use their height to establish how large or how angled a surface is compared to their own body. The use of AR in the field has contributed to the sense of embodiment in the experience—allowing learners to overlay and interact with digital information while on-site using their own body as a reference (Carbonell Carrera & Bermejo Asensio, 2017).

2.4. Enjoyment

Common UX factors include emotion or affect, which is often operationalized as the degree of valence that occurs (Vorderer et al., 2004). With immersive technology, however, successful exposure leads to overly positive affect and emotions and therefore should be explored independently of commonly measured affect and emotion. Enjoyment is an accepted outcome measure in response to immersive technology. Specifically, enjoyment creates a sub-scale of positive affect with degrees of enjoyment or fun when the experience occurs. Enjoyment is strongly related to usability

and considered a factor leading to learner engagement (Ainley & Ainley, 2011). Features of a technology experience that become overly complex or difficult to use can reduce enjoyment.

Enjoyable experiences in education lead to improved outcomes. The role of fun and play have been well established in education as motivation for sustained learning (Bisson & Luckner, 1996). The nuances of fun and the subjectivity of what eventually motivates a learner, however, can cause variation in how well enjoyment improves learning. With increased motivation through fun and play, learning challenges can be increased, forcing a learner to engage with learning content through higher-order thinking skills. The downside to enjoyment in learning can be twofold: a) that experience can be so enjoyable but never increase the challenge such that learners become bored and b) that challenge increases too quickly, and learning becomes frustrating. Focusing on enjoyment alone can additionally lead to poor learning outcomes, and therefore should be balanced with other factors related to learning content (Clark, 1982). Optimal enjoyment of learning content requires aligning the challenge to skill level and requires constant feedback. Learners should be made aware of their capabilities at any given time and be provided timely assistance where their capabilities fall short in order to increase enjoyment.

2.5. Novelty

A particular experience that is entirely new for a user can have profound effects on the initial satisfaction, so much that users often will forgive issues of usability or ignore the content of the experience (Roussou, 2000). Novelty as a UX concept is a unique characteristic compared to other concepts in that it dissipates as the experience persists. It is, therefore, sometimes framed as a negative aspect of the UX experience that must be resolved for effective learning to occur (Dalgarno & Lee, 2010). However, with newer devices and applications being developed, novelty should not be ignored. Users experiencing immersive technology for the first time can experience an overwhelming sense of curiosity and awe, an emotion that can have both positive and negative effects (Chirico et al., 2016). Novelty, while a fleeting experience, generates high levels of engagement from users which can quickly dissipate over some time, providing a false sense of success with a technology experience (Merchant et al., 2014). Novelty impacts engagement through a combination of intrinsic motivation and expectation. The key to effectively integrating novelty in an educational setting, aligning with other media used in learning, is to continually provide something new so the positive aspects of the experience can increase and sustain learner engagement. Keeping the learning experience consistently new can help stimulate a learner's ability to adapt and apply knowledge learned to different situations, much like a repeated virtual simulation can continue to distract patients from pain in therapy sessions (Rutter et al., 2009). In such situations, the novel experience must be sustained to keep patients distracted from the pain they feel. This notion of sustaining the novelty of an experience can potentially help instill higher-order thinking skills as learners have to think through the changing experience. The positives of creating new learning experiences to engage and stimulate higher-order thinking can be similarly applied to the experience of immersive technology. One can hypothesize that the positive effects of novelty in a sustained way could maintain engagement.

3. Theoretical Framework

In this section, we present our theoretical framework, the immersive framework, consisting of UX factors of immersive technology that indirectly lead to learner engagement through constructs that hold meaning for both UX and learning. We explain the theoretical linkages that connect two key characteristics of immersive technology with the UX concepts discussed in the previous section and illustrate how it can lead to learner engagement. We focus on the learning content presented as a representation abstracted from the real-world (representational abstraction) that situates learners through cognitive involvement, akin to experiential and place-based learning. Such experiences afford a sense of agency through active participation in the learning scenario while providing timely feedback to boost motivation and maintain attention. In accomplishing these goals with our curated experience, learners experience UX factors of presence, embodiment, enjoyment, and novelty, to varying degrees, depending on the immersive technology used. These aspects may occur together or individually. Each factor uniquely impacts learner engagement positively or negatively, often depending on the user, the type of technology, and the situation in which the technology is implemented. For example, using such technology in the field through AR to reinforce content covered in lectures will

produce different levels of each factor compared to using VR in the classroom on a rainy day because a field trip was canceled. The results of these two examples will inevitably have different outcomes because of the differences in the situations for implementing different technology. We begin with a description of each aspect of the immersive framework.
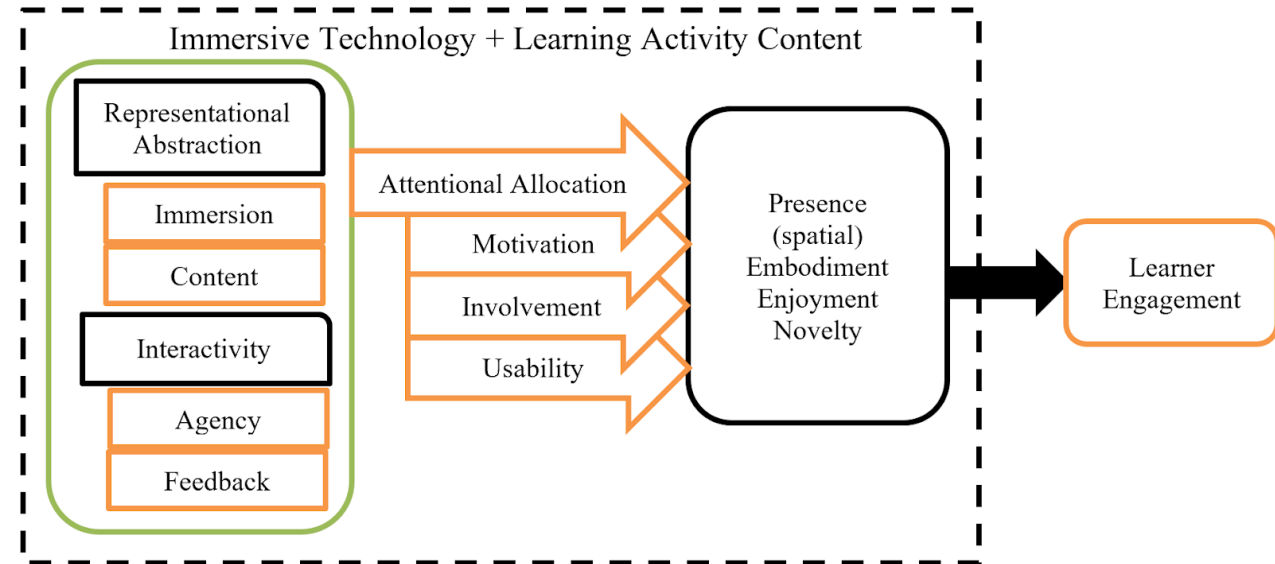
3.1. Representational Abstraction

The immersive framework starts with representational abstraction, the symbolic encoding of information to be learned that is presented through the immersive technology. Representational abstractions come in many forms from text to drawings. Bricken (1990) links symbolic processing in learning specifically to reality generation or the simulated experience. The representational part of the abstraction focuses on the attributes of the technology; in this case, those attributes enhance immersion—field of view, field of regard, level of detail, and many others. These attributes, or affordances, of the technology involve the user's senses as a means to build and present a representation. The other aspect of this concept is the abstraction itself, the content. Not only is the multimodal presentation (multiple-senses) a large part of the abstraction but so is the symbolic information provided. Content in this framework refers to the symbolic information communicated through immersive technology; it is the focus of the learning activity and the surrounding environment—be it the real environment as in AR or a completely synthetic one for VR. According to learning design, the content and context must be defined and related to the intended activity to work with the representation. For example, content on animal habits could be contextualized within the setting of a zoo and presented through immersive technology in ways suitable to the intended learning activity (e.g., if a real zoo was inaccessible), VR could manufacture the experience or AR could be used within a zoo to simulate content in the real-world context. Content is inclusive of anything meant to be interacted with (e.g., tables, graphs, 3D objects, and even textbook passages). Context is the space that holds the content—including the interface for accessing and interacting with content. As in the zoo example described above, the actual zoo would be the context for the additional content using AR while a virtual zoo would contain the same content in VR.

3.2. Interactivity

As noted earlier, immersive technologies are not entirely passive experiences; immersion is often accompanied by some degree of interaction even if the learning experience is primarily designed as a passive one (i.e., virtual tours still afford the learner to look around or click on objects). The ability to act and enact change within a virtual space adds numerous possibilities to the experience (Bucy & Tao, 2007). Sundar (2004) distinguishes between interactivity as a function of the technology and interaction as a user's perception of their ability to enact change through their actions. Interactivity provides a way for learners to act within the virtual place. Interactivity occurs in two ways: the actual system characteristics inherent in the devices used and the metaphor applied to added capability not explicitly tied to the device (Kalawsky, 1999). For example, characteristics inherent in the devices can refer to aspects such as a gyroscope that enables 360° motion of a user's head or physically moving a phone to look around. Added capability, on the other hand, could be a feature within a point and click interface that shifts perspective as a metaphor for walking in a virtual place. Both kinds of interactivity involve the user in the content through taking some form of action and provide varying degrees of control and agency to the user. User agency, akin to learner agency, is the cornerstone of interactivity and represents the user's capability and freedom to control action within the environment. The amount of agency granted to a user can both increase and decrease UX factors of immersive technology, suggesting a need for balance in the amount of control a user has at any given point in an immersive experience. Agency and therefore interactivity are highly tied to motivation and intention, much the same as found with learner agency. Additionally, interactivity relies on feedback to illustrate that an interaction has occurred. Whether as a change in the viewing angle from turning one's head or highlighting an object in an environment, feedback informs users that something has happened (i.e., the user's interaction has done something as well as whether a user has done something right or wrong). A technology's mode of interactivity and method of feedback is directly tied to usability, which can either increase or decrease satisfaction, enjoyment, and learner engagement. Similarly, learner feedback from interaction with an activity can impact the overall learning experience by its timing and incorporation of remediation.

The immersive framework (Figure 1) shows a layout of all of the listed concepts with the theoretical linkages from the main components of a curated learning experience using any immersive technology. Representational abstraction (technology + learning content) and interactivity work together to influence several UX factors that increase engagement with the technology experience and ultimately the learning experience. In this framework, we focus on the interplay of our two concepts influencing UX factors to formulate learner engagement and discuss the potential implications for learning.

Figure 1

Immersive Framework for UX and Learning in Immersive Technology for Learner Engagement

3.3. Attentional Allocation

A central factor to representational abstraction and interactivity successfully influencing UX factors and learning is attention. Attentional allocation plays a vital role in maintaining the focus a learner gives to an activity or experience (Wirth et al., 2007). Learners provide an initial allotment of attention to an activity or experience, but this allotment then varies as a function of UX and individual factors. For instance, as presence occurs, a higher allotment of attention is given towards the experience so that a learner is not distracted by things outside of the experience, regardless of the distraction. This idea of a focused allotment of attention holds similarities to the concept of flow (Nakamura & Csikszentmihalyi, 2009). Attentional allocation is helped by the physical factors of the technology. Headsets, for example, physically block seeing the outside world whereas a mobile phone interface does not. However, mobile phones can use flashing lights and other sensory cues to sustain attention. Similarly, headphones direct sound of the experience towards a user's ears overriding sounds from the real world around him/her. A technology's isolating factors, however, can have adverse effects in certain contexts. For example, collaborative experiences require the ambient noise of others to feel engaged and present. As a result, understanding the immersive attributes of each technology is crucial to aligning the right technology with a specific learning scenario. Similar to UX, learner experience is based on an allocation of attention towards the learning content, often seeking to reduce split-attention to improve a learner's information processing capability (Kalyuga et al., 2000). Oftentimes, attention is attained through a combination of different learning strategies that fundamentally work from the same theoretical linkages as UX from immersive technology: involvement, motivation, and usability.

3.3.1. Involvement

Involvement is the degree a user participates in an activity (Schuemie et al., 2001). From a learning perspective, involvement considers external factors that provide cognitive stimulation, physical interaction, control, potential exploration, and varying challenges (Wishart, 2001). Cognitively, learners are tasked with challenging existing mental

models to form new ones through active learning. Similarly, physical interaction challenges learners to involve their bodies, embodying the learning activity through movement and physically interacting with the material. The involvement of the senses through immersive technology provides the learner with a greater sense of agency that results in enhanced interactivity with activities meant to develop or enhance mental models. Interactivity in an immersive environment (the learning place when immersive technology is used) allows for learners to physically involve their bodies to situate mental models within a real-world context. This can cognitively engage and enhance mental models when compared to learning media that rely on more abstracted information. For example, giving directions using the cardinal directions (survey knowledge) as opposed to unique buildings/monuments (landmark knowledge) is much harder without the proper mental models and surrounding context.

3.3.2. Motivation

Ryan and Deci (2000) suggest that the incentive to participate in a learning event can be internal or external. Internal motivation guides a learner to exclusively focus on a learning goal and ignore issues and other external factors which may detract from the experience. UX concepts of affect and fun/enjoyment directly impact a learner's internal motivation and provide insights into how a learner remains invested in an experience. For example, enjoyment of an experience leads to a learner's heightened investment and capacity to ignore inconsistencies and even bad interface design. External motivators, more commonly found in traditional learning environments, consist of reward-based systems to encourage participation. Grades are often an external form of encouragement to perform well in a learning event and even motivate learners to succeed despite poor design and issues with a technology system. Within active learning, different approaches are used to establish positive experiences through aspects of extrinsic motivation. For example, positive experiences due to subjective outcomes of fun and play are highly correlated with the UX factor of enjoyment (Fontijn & Hoonhout, 2007). A key factor with maintaining motivation from a learning perspective is the balance of challenge to reward (Garris et al., 2002). As a whole, motivation provides the means to engage and continue to sustain a student in a learning activity. In summary, UX capitalizes on motivation through factors of novelty or involvement of the senses to heighten investment with the learning experience. Understanding the relationship between UX and motivation is vital when building activities that develop a sense of involvement and enjoyment to improve learner engagement.

3.3.3. Usability

Usability plays an integral role in how technology influences the experience. Commonly, usability is tied to the satisfaction component of the user experience; however, other aspects of usability can adversely impact satisfaction. Within this study, satisfaction is defined as the rating of usability that can lead to improved or diminished engagement with a technology. There are similarities and distinctions between usability in learning (pedagogical usability) and HCI. Pedagogical usability is similar to HCI's usability factors but focuses on the ability of a learning intervention to address objectives (Ardito et al., 2006). The components of pedagogical usability include everything from the content to the interface and tasks. Consequently, the influence of usability issues in UX can fall under the umbrella of pedagogical usability but with the added need to relate to the learning objectives. Poor UI has similar results to weak instructional guidance in a classroom; if a learner cannot learn the interface, the poor experience will obstruct achievement of the learning object and decrease learner engagement. Good usability within an immersive technology will blend seamlessly into the experience, allowing the learner to focus on the task. Combining good technical usability with the proper design of activities should additionally free up mental resources to focus on the construction of new knowledge from the experience. However, if any single aspect of the experience is not well designed, some learners may not excel in meeting learning objectives as a result of not fully engaging with the content.

4. Implications in Learning Approaches

Learning through immersive technology has focused primarily on a constructivist approach (Bricken, 1990; Dalgarno & Lee, 2010) hinting towards the positive aspects of active learning. The high degree of activity embedded into the immersive experience makes it possible for learners to construct new knowledge through any number of combinations

of situated (Dede, 2009), place-based (Klippel et al., 2019), exploratory (De Freitas & Neumann, 2009), and experiential (Abdulwahed & Nagy, 2009) means. In understanding the roles of learning approaches, we focus on how the framework discussed above helps to bridge the two ideologies towards learning through immersive technology with implications to improve learner engagement and ultimately learning.

De Freitas and Neumann (2009) explain the learning cycle as consisting of three approaches: associative, cognitive, and situative. Associative learning makes use of immediate feedback and transfers to other contexts. Cognitive learning focuses on abstraction and experimentation that builds on the technology experience. Lastly, situative learning focuses on interaction with others, establishing a community of practice. Each approach occurs within a learning event and can overlap depending on the alignment of learning objectives, activities, and outcomes defined. With our framework combining factors relating to both learning and UX, we can provide more technical implications that work within these three approaches. This suggests that different learning approaches can be integrated into the immersive framework to improve learner engagement.

Interactivity through good usability practices and design can improve immediate feedback on learning performance and incorporate remediation in a variety of ways. Good interface design combined with varied activity types can improve transfer from the simulated learning context to the real-world, improving the associative learning approach. Increased agency of movement and learning through free exploration can combine with virtual content and immersive factors to offset the cognitive load of mental abstraction (Chen & Ismail, 2008). This offloading frees up a learner's mental capacity to experiment and develop newer mental models, addressing the cognitive learning approach. Lastly, immersive technology has only recently started to facilitate collaborative experiences (Wallgrün et al., 2019) but does incorporate a connection to an environment, whether real or synthetic, that can house collaborations. The immersive affordances and cognitive involvement, both increasing a sense of presence, can help to establish a connection to the simulated environment—a goal found in the spatial disciplines but increasingly in other disciplines such as medicine and engineering. For example, to help nurses learn an emergency room layout quickly, immersive technology can situate the learner in the environment with indicators of where essential instruments are located. While not forming a community of practice with other learners, the single learner can establish an understanding of the spatial layout – addressing the situative approach.

5. Building Learner Engagement through Immersive Technologies

In this section, we take a look at two innovative examples of immersive technologies being used to enhance learner engagement in the spatial disciplines. We draw our first example from architecture. Design students often find themselves working with smaller-scale, abstract drawings and 3D models that are meant to represent buildings and interior spaces in the real world. During the initial years in a design studio, students develop the foundational skill to visualize the real-world scale of buildings under design. Students acquire this skill through a curriculum focusing on manual tools (e.g., hand drafting, building scaled physical models) and guidance from faculty and peer reviews. However, even with this training, some novice design students still find this skill difficult to acquire. During the design process, novice design students are challenged with understanding the qualities of space, spatial dimensions, and relationships between spaces. Additionally, novice students in architecture and related design disciplines find it challenging to visualize organizational, dimensional, and experiential aspects of built environments (Kalisperis et al., 2002; Otto et al., 2003). Additionally, novice students in architecture and related design disciplines find it challenging to visualize organizational, dimensional, and experiential aspects of built environments (Kalisperis et al., 2002; Otto et al., 2003). Traditional computer-aided design (CAD) tools, often learned and used in the design profession, do not represent built-environments at full-scale, but rather at the scale provided by the size of computer monitor a given student is using. These tools additionally place design students outside of their digital drawings, forcing them to take a mental leap to envision the above aspects without any relation to their bodies. However, immersive technologies, through a sense of presence, allow students to *inhabit* the spaces under design and evaluate their experiential qualities.

To address this issue for beginning architecture students, we utilized immersive technology in the form of VR because design students learn without an actual environment. The Immersive Visualization Lab (iLab) at the University of Missouri and the Immersive Environments Lab (IEL) at Penn State University are based on a cost-effective desktop VR approach using readily available hardware components including large-screen displays, a familiar desktop computing environment, and affordably priced software (Figure 2). The selection of VR technology focused on teaching scale;large screen VR displays use the student's body height compared to the size of the 6' screens for a more embodied reference. Furthermore, multiple screens provided a better opportunity for the field of regard (or inclusion of the student's periphery) to aid in connecting spaces and enhancing the sense of presence through a focus on only the designed space. These immersive systems allow design students to translate their CAD models into an interactive, immersive experience on large-screen, 3D-capable displays. The added stereoscopic 3D capability further enabled students to explore their design ideas through 3D glasses at more accurate scales via interactive walkthroughs from the first-person point of view than from their desktop monitors. The attentional focus produced by full-scale models enabled students to make more associations with their designs and more informed decisions based on not needing to mentally abstract the scale of the design. The overall pedagogical value of the offset of the mental abstraction through the representation (Kalisperis et al., 2002; Otto et al., 2003), as well as the positive impact on spatial understanding and presence of these immersive environments (Balakrishnan et al., 2012; Balakrishnan & Sundar, 2011; Kalisperis et al., 2006; Oprean, 2014), has been demonstrated through controlled experiments as beneficial to the education of beginning design students. The students not only find the experience engaging but also find the novel format helpful to explore their designs and make better design decisions. These experiments specifically looked at the impact of VR on spatial understanding and spatial presence systematically as a function of various affordances of immersive technology including stereoscopy (e.g., the 3D effect), the field of view, level of detail, and navigability among others to identify the actual value of each for design students. For instance, the field of view was the most influential attribute of immersive technology for learning scale, navigability was influential for engaging with the content, and the usability of the system's navigation and setup made the use of the immersive systems successful or unsuccessful. Motivation in this example was intrinsically provided by the student's interest in improving their designs through a different experiential medium than the traditional CAD tools and physical models. Overall, students were more engaged with the design experience when using the immersive systems as it forced them to think through their design decisions made while working on a smaller desktop computer.
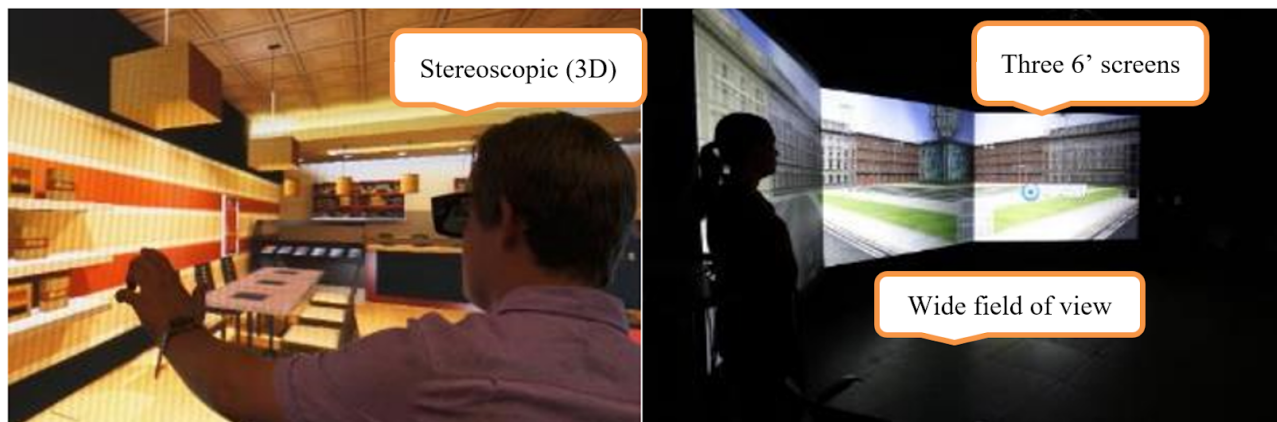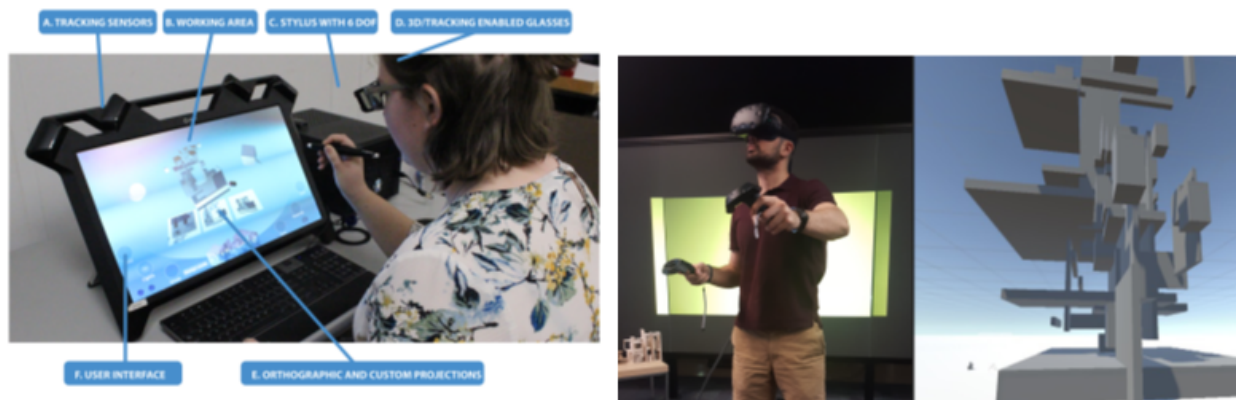

Figure 2

Design Explorations in the iLab (left) and the IEL (right)

A second and third example from architecture focuses on another aspect learned in the first years of design education —composition and exploration of design (or ideation). Given the challenge in learning and applying both composition and exploration of design in early studies, the framework applies not only one immersive technology but two. Nine Cube VR (Hopfenblatt & Balakrishnan, 2018) is a digital learning tool consisting of two modes, desktop VR and headset VR, for beginning design students in architecture to learn basic principles of 3D composition and design exploration. The Nine Cube VR is an immersive virtual reality implementation of a classic foundation studio course exercise developed

by Hejduk (1985) that provides students with a "kit of parts" along with several constraints on dimensions and transformations for design exploration. This well-established design studio exercise provided the learning content while the two immersive technologies involved provided varying levels of representation to assist with the different parts of the learning scenario. In addition to the pedagogical goals related to 3D composition, form, and design, the immersive virtual reality tool takes advantage of newer mediums such as stereoscopic 3D displays and interactive input devices. These mediums have the ability to switch between smaller scales that architects work with during composition and massing explorations at full-scale. It also allows students to experiment with interactive lighting studies relative to the level of detail available in VR. The combination of technical attributes helps to establish a sense of presence in the open virtual place where the design content can be manipulated as part of the learning activity. Unlike with the large-scale screens used in the other example, embodiment is not as present with the fixed display and narrower field of view from Nine Cube VR's desktop-mode but is compensated through the use of the HTC Vive VR headset (Figure 3). As a result, the involvement in the desktop mode is dependent on the interaction with the content in the virtual place, but embodied interaction drives the VR headset experience. Feedback from students and instructors was positive and pointed out its potential for improving student designs through the engagement resulting from being able to address both the experiential and composition stages of design ideation.

Figure 3

Comparison of the Nine Cube VR in the Desktop Mode (left) and the Real-Scale Mode (right)

6. Conclusion

The immersive framework presented in this chapter addresses the perspective of UX factors impacting learning by influencing the degree of learner engagement. We discussed several known UX factors and their ability to impact learner engagement , particularly the role of spatial presence and its ability to situate learners. The immersive framework serves to address the growing tendency in education to implement immersive technology and focus exclusively on either learning effectiveness or the technology. Immersive technology comes in several forms and should be considered based on the commonalities that lead to immersion. Using a variable-centered approach, we looked at how the technology's attributes enable key concepts in UX, usability, and learning to establish learner engagement. In this chapter, we covered select technical attributes that comprise immersion and focused on primary factors of visual immersion as an illustrative means for the immersive framework.

In the application of the immersive framework, we note that usability factors cannot be ignored because UX and usability are closely connected and can highly impact learner engagement. In the case of novelty, we find that some aspects of usability do not carry as much weight in the overall experience rating. Therefore, in applying this framework, usability should always be considered to reduce any undue influence of poor interface design which reduces satisfaction and ultimately learner engagement. The examples described in the previous section illustrate use-cases in architectural education where immersive technology has been effectively implemented to improve learning outcomes.

Limitations we noted in the immersive framework include the need for well-designed learning activities and clearly identified learner needs before applying the framework to select and implement immersive technology. For the implementation of the immersive framework beyond the spatial disciplines, the choice of immersive technology should support the intended learning scenario (e.g., field trips augmented with AR or replacing field trips with a VR experience). Each option presents a different way to approach content covered in a field trip but through different technology. This choice comes down to aligning the design of the intended learning activity with the format of the representation and content with the interaction. In cases such as the Nine Cube VR example, two forms of VR were used to accomplish the intended learning need, and the framework was applied to both technical attributes implemented to sustain learner engagement. Another possible limitation pertains to the numerous learning approaches that address how learning occurs as the immersive framework focuses on technical implementation. Despite the push for immersive technologies to be used for active learning, passive approaches can be used as well (e.g., virtual tours as opposed to virtual activities). Alternatively, the strengths of the immersive framework help to shape our understanding of how various immersive technologies can form and sustain learner engagement through each technology's different attributes. This strength explains how different immersive technology can be used for the same activity but provide different levels of learner engagement. Overall, the immersive framework helps provide a better understanding of the attributes specific to immersive technology and how they work to impact factors leading to learner engagement.

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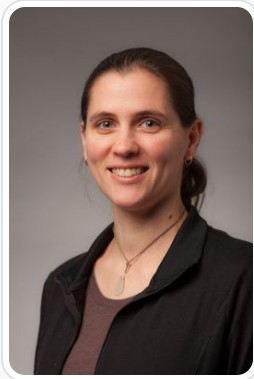
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Intentional Learning Design for Educational Games: A Workflow Supporting Novices and Experts

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Pedagogy   Learning Experience Design   Game-based Learning   Serious Games   Game Design

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This chapter proposes that learning experience design (LXD) and game-based learning (GBL) are mutually beneficial conceptual frameworks for increasing the effectiveness, appropriateness, and user experience of educational games. Drawing on a range of theories, five core LXD principles are defined. LXD is: human-focused, enjoyable and/or playful, goal-oriented, situated and relevant to learner's desires, and placed in supported environments and/or platforms. These principles are mapped to aspects of GBL, proposing considerable overlap between these disciplines, and supported by a wide range of literature. LXD principles are then suggested as solutions to some current challenges in GBL. A workflow is presented which synthesizes interdisciplinary GBL and LXD design processes and offers guidance suitable for GBL designers at a novice to expert level. The workflow categorizes GBL activities into related disciplines (Instructional Design, Empathy/Emotional Design, Interaction Design, and Game Design) to assist readers in analyzing where their own skills or skill gaps lie. A worked example illustrates every activity within the workflow, including practical methods of mapping learning mechanics to game mechanics and of performing gameplay loop analysis. The workflow aims to increase the rigour of GBL design and ensure it benefits from LXD principles, addressing a prevalent challenge in GBL design by focusing on the importance of both an appropriate pedagogical foundation and the needs and desires of learners.

1. Introduction

Learning experience design (LXD) is an approach that foregrounds learners and their desired outcomes in a goal-oriented way, acknowledging individual experience. This chapter proposes that game-based learning (GBL), with its focus on maintaining flow, increasing motivation, and embedding learning, can be a highly effective tool within LXD. Readers can increase their understanding of effective GBL processes using the guided workflow for intentional learning design for educational games, which draws on systematic analysis and matching of learning objectives, learning behaviors, and game mechanics, within an LXD framework. This step-by-step design process will also explicitly identify where GBL benefits from an LXD approach. The workflow is suitable for novices and experts alike; it identifies different disciplinary expertise at each stage and works through a simple example with additional references for GBL designers to follow up. Throughout the workflow, learner experience is at the centre of the process. Reflection on the workflow

provides opportunities for readers to identify their own strengths and weaknesses as LX designers using GBL in their own practice.

2. Theoretical Context

2.1. Mapping LX Principles to GBL

LX research identifies various sets of guiding principles or opportunities for LX designers (Floor, 2018; Jagger, 2016; Raybourn, 2016; Rosencheck, 2015). Whilst there is some variation, core LXD principles are defined across the literature as:

- human-focused (encompassing personalisation, emotion, and experience),
- enjoyable and/or playful,
- goal-oriented,
- situated and relevant to learner's desires,
- taking place in supported environments and/or platforms.

Previous research on LXD applies these principles to online e-learning systems (Dinimaharawati, 2013; Jagger, 2016; Park & Lim, 2019); however, games are also closed interaction systems within a much wider instructional and human context and it is therefore useful to consider them as case studies alongside the general principles of their design. In mapping the different interdisciplinary elements of LXD, Floor (2018) places game design towards the goal (as opposed to the human) centred end of the spectrum. This chapter argues that existing limitations or weaknesses of GBL can be addressed by taking a more learner-centred approach. Each core LXD principle is analyzed below, showing commonalities with the characteristics of GBL and demonstrating that, as an educational approach, GBL can fit closely with LXD principles.

2.1.1. Human-Focused, Emotional, and Personal

LXD is variously described as "learner-centred" (Rosencheck, 2015), "focuss[ed] on the learner" (Floor, 2018), and "put[ting] the human back at the centre" (Jagger, 2016); within LXD the learner's needs, experiences, desires, and emotions are crucial. Park and Lim (2019) state that "emotions directly and indirectly affect students' learning" (p. 53) and note that, despite limited representation in the literature, there is an increasing emphasis on emotional design across many fields, reflected in a range of studies on emotion and empathy in teaching and learning contexts (e.g., Kay & Loverock, 2008; Park & Lim, 2019; Tangney, 2014; Tracey & Hutchinson, 2019). Emotional design is also core to GBL, primarily in consideration of GBL increasing learner motivation and confidence as affective and motivational outcomes are evaluated alongside cognitive outcomes (Clark et al., 2016; Hainey et al., 2016). Both fields acknowledge and foreground *affordances* (i.e., properties of a system that lead to or trigger human action) as having an emotional as well as a functional role. Notably, standardised ways of evaluating emotion have been developed within GBL and, in wider terms, UX research (e.g., Bernhaupt, 2010, passim; Brockmyer et al., 2009).

LXD principles recommend high levels of personalisation and "humanity" in interactions (Jagger, 2016; Park & Lim, 2019) when creating personal learner journeys through games (driven by players' goals and enabled by their power over a choice of interactions) and have been a core concern of GBL research for well over a decade (Bellotti et al., 2013; Hauge et al., 2015; Lepe-Salazar, 2015). Player agency and control over game narratives and interactions is woven into both interaction design within GBL and the affordances of the game systems themselves (see Abbott, 2019a; Lim et al., 2013).

2.1.2. Playfulness, Fun, Enjoyment

Playfulness is defined as a core design principle for increasing the emotional affordances of learning situations (Park & Lim, 2019; Weitze, 2016) and overlaps significantly with the "fun" or "enjoyment" outcomes described across the literature for both LXD and GBL. *Play* has been defined in a number of ways by different theorists; however, the widely accepted characteristics of play are that it constitutes a voluntary activity, lacks (or has negotiable) real-world

consequences, and, crucially, must be perceived as such by participants. For some, this perception of playfulness is all that is required for an activity to become play, and play cannot otherwise be defined as any one thing (Glenn & Knapp, 1987, p. 52). In his book *Play and the Human Condition*, Henricks (2015) defines this playful "disposition" as creating different motivations from those associated with other things we do and having the "distinctive quality of curiosity and enthusiasm" (pp. 28-29), which are both widely accepted as drivers for learning. Games harness the power of playful disposition but add the structure needed to guide players towards particular goals. Juul (2003) defines six features that characterise games:

1. Rule-based;
2. Variable, quantifiable outcome(s);
3. Different potential outcomes are assigned different values;
4. The player invests effort in order to influence the outcome;
5. Players care about the outcome;
6. Negotiable real-life consequences.

GBL uses the rules, outcomes, and values of games to structure learning content in a way that can be experienced by an invested, effortful learner with a playful disposition, in much the same way as learning environments structure their content.

2.1.3. Goal-Oriented, Manageable, and Progressive

The goal-orientation of LXD can be easily mapped to games' "win conditions" or completion. Typically, a game's completion state is built on interim goals contributing to the overall learning outcome, a common structure directly reflected in multiple game levels, or missions building on previous expertise that progress to a final goal once mastery has been achieved. In the context of e-learning, Jagger (2016) calls this design structure *chunking* (i.e., learning content being broken into bite-sized pieces). In both LXD and GBL, chunking allows multiple individual interactions, which ideally provide immediate feedback, offers a chance for learner reflection, and builds on their overall understanding. These interactions provide individual pathways towards a coherent and understandable end point, resulting in personalised learning over which the learner has a considerable degree of agency.

The overlap between manageable, progressive goals and learner emotion is clear, and a learner's perception of success in achieving their goals is confirmed in literature across LXD, GBL, and pedagogy more generally as supporting the process of learning. The LXD principle of *Positivity* is related to the learner's confidence in being able to achieve learning completion (i.e., their final goal: Park & Lim, 2019). Again, these principles are reflected in GBL literature with multiple considerations of their relationship to players' experience of *flow* or intensified concentration (e.g., Hamari et al., 2016). Further examples are available which map this specific learning mechanic to related game mechanics of Behavioural Momentum and Cascading Information (Abbott, 2019a; Arnab et al., 2015). Feedback also contributes to emotional design (Park & Lim, 2019) and is highlighted as a priority in LX-informed GBL as critical for both learning and engagement (Dodero et al., 2015, p. 187).

2.1.4. Situated and Relevant

LXD recommends that learning is well-situated within a relevant context (Jagger, 2016; Rosencheck, 2015) and emphasizes that learner experience is crucial to maintaining relevance (Huang et al., 2019, p. 92). GBL theorists also highlight that learning must be situated in terms of both environment and interactions (Catalano et al., 2014) and propose specific mappings between learning mechanics (such as identify) with game mechanics (such as role-play; Abbott, 2019a; Lim et al., 2013). *Learning mechanics* (LMs) refers to the pedagogically constructed actions used to achieve the learning outcomes, distilled into specific interactions (Lim et al., 2013). GBL can develop this concept further by providing fictional contexts or simulations that serve as a *safe space* to practice skills or behaviors without fear of failure.[1] Significant overlap exists between designing for situated learning, reinforcing motivation for learning through human-centred, empathetic design, and creating learning outcomes that match learners' own goals.

2.1.5. Supported Environments/Platforms

The sections above show that GBL can provide a structure that matches LXD principles by harnessing learners' motivations to guide them both emotionally and cognitively through a responsive learning environment towards their goals.

Therefore, GBL and LXD are congruently dedicated to foregrounding a human-centered, personal experience, which acknowledges players' emotional experiences alongside their intellectual goals. A well-designed, educational game can engage learners closely with its content and interactions, often resulting in a highly immersive and emotionally-engaging learning experience as learners pursue their own particular game-enabled learning goals. Furthermore, game interactions (and the user's control over them) can result in a strong sense of personal identification, agency/responsibility, and ownership over the learning journey.

2.2. GBL is Hard to Develop (Well)

However, despite a growing demand for GBL (Westera, 2019, p. 59), the challenges around its development remain (Abbott, 2019b; Lameras et al., 2017; Ney et al., 2012). Systematic research has shown that simply because learning takes place in a game-based medium does not make GBL homogenous across different games (Clark et al., 2016). Further research links different game characteristics (e.g., such as mechanics, visuals, narrative) with different learning behaviors of players (Abbott, 2019a; Grey et al., 2017). The complexities of implementing GBL highlights that, despite games being able to empower learners to create personalised pathways through the material, these interactions are still defined by the affordances of the game system, platform, and overall learning environment. Furthermore, in order to be effective, GBL requires significant interdisciplinary expertise spanning game design, interaction design, and pedagogy (Bellotti et al., 2013), making it a complex and resource-intensive process.

Despite these well-researched linkages between learning behaviors and game mechanics, many GBL interventions fall short of their potential effectiveness and efficiency,[2] partly due to significant barriers in terms of resources and expertise and partly due to the emergent understanding of this interdisciplinary subject. Very little research to date provides a framework which pairs game elements and learning at either a theoretical or empirical level, and this results in educators being "overwhelmed by the plethora of design choices and level of complexity entailed in integrating, combining and balancing learning with game features" (Lameras et al., 2017, p. 990). This overlooked, explicit interdisciplinary link between pedagogy and game design reinforces LXD's potential role in advancing GBL towards a more human-centred approach by synthesizing player experience with instructional design. Games without a strong pedagogical and learner-focused foundation are likely to fail (Lepe-Salazar, 2015; Westera, 2019) and, without significant interdisciplinary expertise, presenting learning elements as games could create uncertainty and misalignments (Bellotti et al., 2013; Lameras et al., 2017). Furthermore, "The role of the teacher in guiding learning via games seemed to be fuzzy and unclear and may lead to confusion during the design stage, game play and after the end of the game" (Lameras et al., 2017, p. 974). Games and curriculums are experiences designed to engage their respective audience; however, because experiences are unique to each individual, a potential for a disconnect still exists between the designer and the player and/or the educator and the learner (cf. Grey et al., 2017, pp. 64–65). These barriers could be ameliorated if GBL design activities were more explicitly informed by LXD.

2.3. GBL Benefits From an LXD Approach

By exploring experience-based pedagogical concepts for GBL, a 2019 article by Westera identifies several improvements that could be applied to GBL, which are of particular relevance within the LX conceptual framework. Games are highly constructivist and rely on an experience-based approach, and Westera (2019) aligns with LXD literature in stating that learning from experience is the dominant pedagogical paradigm (El Mawas et al., 2018; Floor, 2018; Tangney, 2014). He then critically evaluates available evidence to identify common potential weaknesses in GBL design (summarised and analysed in Table 1, which also suggests the most relevant LXD principles to address each). These issues can be tackled if GBL design takes place within the LXD framework, to which it so closely aligns as shown above. However, despite the shared characteristics of LXD and GBL, this approach is not yet widespread or at least not explicitly articulated as such.

Table 1

Mapping Common Weaknesses in GBL Interventions to Potential Solutions From an LXD Framework

Potential GBL weaknesses (Westera, 2019)	LXD-informed improvements (synthesised from previously cited LXD and GBL literature)
Emphasis on rote learning over deep understanding	Focus on learner, learner-defined goals, frequent feedback, space for reflection, reward playful exploration and experimentation, situated learning
Minimal guidance and scaffolding	Chunked learning, acknowledging surrounding teaching and learning context, interactions outside the game where appropriate, empathetic design, "safe" and relevant learning environments
Shallow pedagogical foundations	Explicit use of LXD framework to inform GBL design, embracing emotional design, mapping learning behaviors to game affordances
Imbalance between immersion and cognitive load	Situated learning in relevant and familiar contexts, focus on learner-defined goals over system goals, chunked learning content, learner reflection
Relationship of reward systems with extrinsic and intrinsic motivation	Empathetic design, emphasis on learner's intrinsic motivation(s), progressive sub-goals
Differences between player performance and learning progress	Close alignment of game mechanics with learner goals, positivity principle, space for reflection, interactions outside game context

The remainder of this chapter focuses on a guided workflow for developing effective and learner-centred educational games. The aim is not only to increase interdisciplinary expertise in this area but also to mitigate some of the barriers faced by educators choosing to use a GBL approach.

3. Design Method: A Workflow for Both GBL Novices and Experts
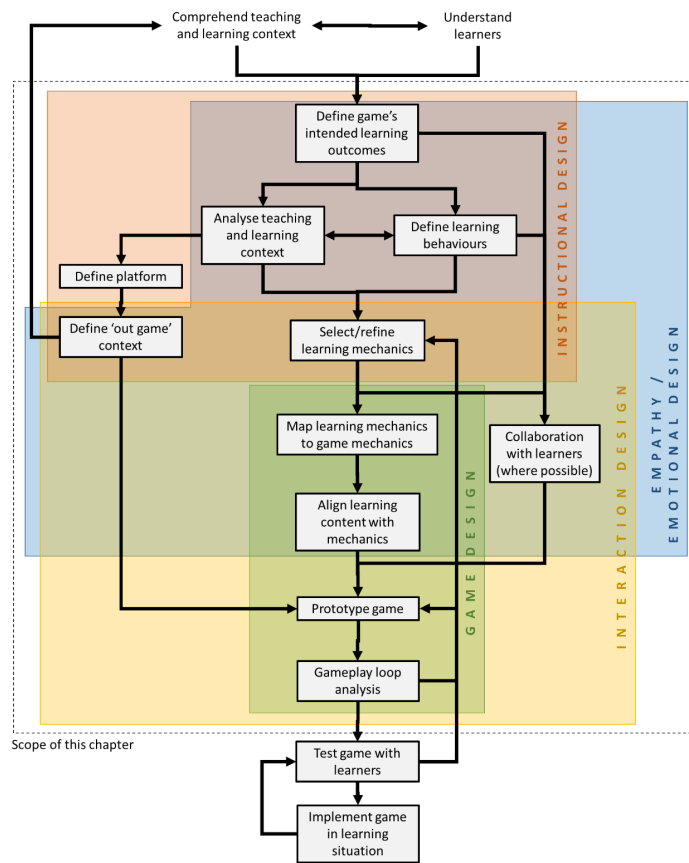
Figure 1

Learner Experience Focused Workflow for Systematic Design of Game-Based Learning Interventions

The workflow presented here (Figure 1) synthesizes elements from existing GBL design models (Catalano et al., 2014; Grey et al., 2017; Lui & Au, 2018; Marne et al., 2012; Nicholson, 2011) with a particular emphasis on those aspects most important to LXD by incorporating the design processes proposed by LXD experts (Floor, 2018; Rosencheck, 2015). It should be emphasised that the focus is LXD principles *specific to designing one particular intervention* – the workflow is situated within Plaut's Interaction and Sensory planes, namely "What will learners actually be doing, hearing, and seeing during the learning experience?" (Plaut, 2014). Clearly, this question's answer must arise from an overall comprehension of the learning context which can include curriculum requirements, organisational parameters, and, of course, early consultation with learners as advised in LXD; as Plaut (2014) states, "To use these methods effectively, you must have a strong grasp of your learners' perspectives and experiences as they relate to the content" (Interaction plane section). However, these wider contexts can differ widely and are outside the scope of this chapter. Similarly, game testing, deployment, and evaluation are crucial steps in this process but these deserve a chapter of their own and will not be discussed in detail here. The dashed bounding box in Figure 1 demonstrates this chapter's focus within the wider LXD context.

The workflow incorporates GBL guidelines specifically aimed at educators (Marklund, 2014; Torrente et al., 2011), recognising that GBL is highly interdisciplinary and requires strong pedagogical as well as game design foundations. Shaded boxes in Figure 1 attempt to show the different specific disciplines within LXD used at each stage and emphasize the need for learner-centred empathy.

The workflow begins by drawing on understandings from the higher planes of LXD: Strategy, Requirements, and Structure (Plaut, 2014). The initial phases of "Comprehend teaching and learning context" and "Understand learners"' feed into Instructional Design activities such as definition and analysis of learning objectives, teaching and learning context, and appropriate learning behaviours and experiences. These activities overlap with Empathy/Emotional Design,

progress into Interaction Design, and culminate in Game Design as learning content and mechanics are systematically matched with game mechanics (Lim et al., 2013). These activities are based on input from learners wherever possible, and linked back into the game's LXD context by explicit consideration of out-game interactions. Finally the game is iteratively tested.

Each step in the workflow will now be considered in detail and illustrated with a practical, worked example for a non-digital game: a simple intervention in a primary school mathematics context.[3]

3.1. Define Intended Learning Outcomes

Defining the intended learning outcomes (ILOs) for the specific GBL intervention is core to the workflow: "you start with formulating the desired learning outcome and every next step in the design process, including the choice of your medium or technology, is geared towards the desired learning outcome" (Floor, 2018). If this seems like an obvious statement, remember that, despite the recognition of ILOs as vital elements across the literature on LXD and GBL, recent reviews still identify significant challenges in linking learning content to game interventions (Lameras et al., 2017). Educators may already know what their learners want the game to achieve and will therefore be able to derive appropriate ILOs for the individual game. However, educators often expect too much from games (for example, a game to assist in teaching the content of an entire course); a position usually doomed to failure. For GBL to be effective, the ILOs must be manageable. ILOs can cover knowledge, understanding, and attitudes; however, it is recommended to keep the ILOs: (a) few in number, (b) specific and focused, (c) well scoped, (d) achievable, and (e) measurable.

3.1.1. Simple Example: Curriculum-Derived ILOs

Maria is a primary school teacher who has noticed that her pupils struggle with comprehending and verbally articulating the concept that the order of terms in a multiplication equation makes no difference to the result. Although her learners are too young to participate directly in game design, Maria has previously had good results and great feedback when delivering unusual and interactive teaching activities. She defines the following ILOs. Pupils should:

1. Understand that, when multiplying numbers, the order of numbers does not change the result;
2. Know the meaning of the term *commutative property*;
3. Feel more confident about multiplication and this terminology.

These ILOs are achievable and specific—for example, while knowing that 4x5 and 5x4 both = 20 is useful, Maria is less interested in pupils knowing the answer than understanding the core concept. These ILOs will be foregrounded and referenced throughout the entire workflow, maintaining goal-orientation.

3.1.2. Extended Example: ILOs

LXD principles recommend consulting with learners on the specifics of the design and, where possible, directly involving learners in the design process. Whilst for Maria the learner involvement may be limited to testing her prototype and iteratively improving it over time, many other learning contexts support a much higher level of learner involvement and co-design. Refer to the work of Marklund and Alklind Taylor (2016) for more on co-design. Additionally, Floor (2018) provides a useful template for analyzing the overall teaching and learning context in the LX Canvas tool.

3.2. Analyze Teaching and Learning Context

The teaching and learning context specific to the intervention covers where and when the game will take place, how long it will take, how often it will be played, how many players it must support simultaneously, what materials or technology it needs, who (if anyone) will be supporting it, and so on. A common pitfall in GBL is for games to be developed in isolation of their context. Typically, the learning context is largely externally defined (e.g., a class has 30 children and lasts 50 minutes), but, even within strict parameters, some flexibility exists. Designers must consider questions such as, "Will the game be played together in class and supported by a teacher?" or "Is the game intended for independent study at home?" Therefore, designers must contemplate how GBL will be effectively integrated into

teaching and learning practice in a way that is most effective and responsive to learner needs (Catalano et al., 2014; Marklund, 2014).

3.3. Define Platform

Platform refers to what specific delivery mode the game will have (for example, an app, board game, physical game, PC game, virtual reality). The delivery mode is defined largely by what tools are accessible (for example, there is no point trying to design a collaborative app if the school has only one tablet and a patchy wifi connection), but, again, flexibility exists and it is important that GBL design considers learner preferences rather than defaulting to the easy or most obvious platform. Whilst the example here is a physical game, the principles can also be applied to digital GBL.

3.4. Define Out-Game Context

Gameplay is affected by more than merely the features of the game itself. An *out-game* action is defined as an action which does not have an immediate and measurable effect within the game but nevertheless mobilizes perceptive and cognitive capacities and provokes *in-game* actions (Guardiola, 2016). Out-game actions are particularly important when using GBL within an LXD framework as this is where much of the learner reflection, support/guidance, emotional design, and authentic linking between game and wider context takes place. Some useful examples to consider are:

1. A tutor prompting or reinforcing learning from a game event,
2. A player vicariously learning from something another player does and adapting their own strategy in response,
3. Players collaborating to achieve a goal, or
4. An educator encouraging reflection on learning.

The context in which out-game actions take place could be externally imposed but still need to be considered critically to ensure the learner's needs and goals remain central to the process. One powerful example is that games provide a space for learners to behave differently, experiment, and fail safely, and evidence shows that being observed by non-players can break the "magic circle" of the game, embarrass players, and inhibit playful and/or learning behaviours (Huizinga, 1955).

3.4.1. Simple Example: Learning Context, Platform, and Out-Game Context

Maria's learning context is within a primary school class of 30 children, with no teaching assistant, so the game must engage all learners at the same time with only one facilitator (Maria). She will be present at all times, leading and supporting the game and providing explicit assistance to learners who need additional support. The game platform must be immediately familiar to learners to prevent distraction from their learning goals; in addition, Maria has no budget for additional technology or tools. Maths lessons take one hour and (drawing on context external to the intervention) Maria wants the ILOs to be achieved in one lesson, with limited repetitions of the game.

3.5. Define Learning Behaviours

An absolutely crucial step in GBL design within an LXD conceptual framework is understanding "how" as well as "what" players are expected to learn. A common mistake is to default to a familiar *question and answer* model (e.g., Trivial Pursuit) where the learning behavior is in fact simply recalling knowledge the student already knows. This behavior is closer to a test than a game and is poor at enabling learners to embed new knowledge or understanding (Nicholson, 2011). Instead, top-level behaviors that support learning should be defined, such as:

1. Will players collaborate, co-operate, or compete?
2. What existing skills/knowledges are required and how will they be recalled/developed?
3. How might physical movement complement the emotional and cognitive outcomes?
4. Is repetition needed for reinforcement?
5. What are the learning behaviours that suit the learners best and will most effectively help them reach their goals?
6. What is the emotional as well as cognitive impact of particular learning behaviours and their results? and
7. What behaviours are likely to increase enjoyment and motivation?

It is quite clear that learning to play a scale on a piano requires different learning behaviours than learning to analyse a painting. A useful guide can be found in *Production of Creative Game-Based Learning Scenarios: A Handbook for Teachers* (Torrente et al., 2011).

3.5.1. Simple Example: Learning Behaviours

Based on previous feedback from her learners, Maria identifies suitable learning behaviours compatible with her teaching context:

- The main learning behaviour must emphasise equivalence between sums (i.e., recognition, matching, grouping, or reordering);
- Cognitive processes must take place within interactions the pupils already know how to do;
- Learning must be active and collaborative;
- Repetition is required to reinforce learning and support pupils who are slower to grasp the concept;
- All children must be involved all of the way through (i.e., no-one is "knocked out");
- Learning behaviour should be novel (i.e., disrupting normal classroom behaviour);
- Physical actions must be aligned with cognitive concepts; and
- Pupils' learning should be self-directed.

Maria is foregrounding empathy in her design. She believes that, if the children have fun, feel ownership over the process, and disrupt usual classroom behavior, they will better learn and remember the ILOs.

Using both context and desired behaviors, Maria defines the platform as a physical game (i.e., the children will move around, matching and forming groups). She decides that the game itself should take no more than 30 minutes with out-game actions including explanations, scaffolding, and reinforcing the principle with applied examples in the lesson time remaining after the game ends.

3.5.2. Extended Example: Learning Behaviors

Learners should ideally be closely involved in co-designing their own learning behaviors to ensure personalised learning pathways, goal-orientation, and appropriately supported environments. Defining learning behaviors with explicit learner input could be achieved by observation, consultation, or co-design. Where possible, GBL interventions should be designed flexibly to allow multiple learning behaviors (as learner groups are rarely homogenous). For example, players could be offered the choice of whether or not to play "against the clock."

3.6. Select/Refine Learning Mechanics

Once overall learning behaviors have been defined, more specific actions and interactions for achieving learning outcomes can be identified (learning mechanics). GBL novices could start by putting these mechanics into their own words; however, it would also be useful to use or take inspiration from any pedagogical framework with which the educator is already familiar (e.g., Bloom's revised taxonomy verbs; Anderson & Krathwohl, 2001). More experienced GBL designers could work from a framework specifically for GBL, such as the LM-GM model (2015) which provides "a non-exhaustive list of learning mechanics that have been extracted from literature and discussions with educational theorists on 21st century pedagogy" (Arnab et al., 2015, p. 396). What is important at this stage is not the exact taxonomy used but clarity of the precise actions that will lead to learner engagement with the ILOs.

3.6.1. Simple Example: Learning Mechanics

Maria has used Bloom's verbs before and she identifies the following specific LMs which would help learners to acquire the ILOs.

- ILO 1: recognise (identical sums), identify (equivalent sums), compare and contrast (different and equivalent sums), connect/correlate (equivalent sums), transfer knowledge (to other equivalent sums)
- ILO 2: recite (the terminology)
- ILO 3: memorise (the terminology), relate/transfer (the property to other sums), collaborate (across groups with equivalent sums)

3.6.2. Extended Example: Learning Mechanics

Using the LM-GM model, similar LMs can be defined:

- ILO 1: instruction, guidance, participation, action/task, identify, ownership, repetition, generalisation
- ILO 2: imitation, ownership, repetition
- ILO 3: imitation, ownership, responsibility, generalisation, feedback

3.7. Map Learning Mechanics to Game Mechanics

Game mechanics (GMs) refers to interactions with the game state, engaging players with the content. In other words, GMs exist to frame the game experience within the defined rules and to guide players in understanding the interactions required to participate (Lim et al., 2013). GMs affect game strategy and flow and require emotional as well as cognitive design. Explicit linking of pedagogically-founded LMs with GMs allows designers to ensure that an educational game focuses on the behaviors they want to encourage and that players can encounter learning content in the way that is most suitable. Arnab et al. (2015) call the resulting match a *Serious Game Mechanic* (SGM) and state that "SGMs reflect the complex relationships between pedagogy, learning and entertainment/fun, joining educational and gaming agendas. Therefore, SGMs are the game components that translate a pedagogical practice/pattern into concrete game mechanics directly perceivable by a player's actions" (Arnab et al., 2015, p. 395). By identifying SGMs, their LM-GM model enables further rigor in the analysis and evaluation of games in educational settings. In reality, this stage of the workflow is likely to overlap with the next one, creating a series of swift, intuitive iterations of all steps within the Interaction Design category shown in Figure 1.

3.8. Align Learning Content with Designed Mechanics

In this step, actual learning content (in our example, multiplication tables and math terminology) is aligned with each in-game and out-game action. These interactions then enable learners to construct the knowledge needed to achieve their goals. Whilst there may certainly be overlap here with earlier stages of the workflow, ensuring the core game mechanics create the right learning behaviors is crucial. Ensuring learner interactions are appropriate before the game is "skinned" with actual learning content emphasizes the learner-focused approach (i.e., a mode of engagement that is personal, supported, and goes beyond instructional design).

3.8.1. Simple Example: Mapping LMs to GMs and Aligning Learning Content

Using the LM-GM model, Maria maps her LMs as follows: To embrace collaboration, social learning, and enjoyment, the whole game will be based on communal discovery. Pupils will be allowed to discuss and help each other as they play. Game cards (randomly assigned) will contain learning content (some identical, some equivalent sums). Identifying/matching actions function as collecting all identical or equivalent sums together. Grouping will be through physical movement which reinforces the cognitive matching and quick feedback as grouping happens (as the learners realise that all sums in their group are either identical or equivalent) which reinforces the Identify and Connect LMs.

Maria's class tends to enjoy and learn more if they believe they can achieve the task. She knows their "growth mindset" can be mapped to the urgent optimism GM. Therefore, content cards will start very easy and progress in complexity/difficulty. Recitation/imitation of the terminology must be included in the game. Repetition of the game for memorisation and confidence is mapped to behavioral momentum.

3.8. Prototype Game

The mechanics are now ready to be structured into gameplay. Prototyping is again likely to happen as a series of swift iterations, with early ideas being refined mentally before any material prototype is even attempted. It is certainly recommended to consider the next step (gameplay loop analysis) at least once and go through the recursive part of the workflow again before investing time in creating any game materials.

3.8.1. Simple Example: Prototype Game

For learners to achieve the ILOs, the collecting GM must be central to the process and the terminology must be included too. Maria's initial game idea is as follows:

- Pupils will be randomly assigned cards with multiplication sums written on them. Each pupil will get one card. Cards will be produced such that three equivalent groups can be formed (of 10 pupils each). Within each group, some sums will be identical and some sums will have the same terms but in a different order.
- Pupils will find their matches/equivalents and form physical groups based on their cards.
- Maria decides that shouting out the word "Commutative!" once a group has formed is a fun way to cement the terminology and acts as a "finishing point." This will need an out-game action (the teacher speaking the word and asking pupils to imitate) in the early stages.
- As the pupils learn the concept, the game can be made harder (e.g., with more groups, sums, more than two terms).

3.8.2. Extended Example: Prototype Game

Game prototyping offers fruitful opportunities for learners to become directly involved in the co-design of their own learning activities. Whilst Maria's options may be limited due to the very young age of her pupils, she directly involves the pupils in creating the game cards by printing out word and sum templates for the children to colour in. This builds ownership over the process and excitement for the first playtest.

GBL designers working with adults or older children can improve their learner-focus by working much more closely with learners at all stages of the workflow. This is likely to be particularly useful in the Define learning behaviors, Align learning content, and Prototype stages. If working directly with learners is not possible, data about their goals, preferences, etc. could be gathered to inform the process.

3.9. Gameplay Loop Analysis

Gameplay refers to any interaction with the game and, in the context of LXD-informed GBL, explicitly includes non-tangible emotional and cognitive actions/reactions as well as physical actions influencing the game world. A gameplay loop represents gameplay as linked actions, by breaking down and describing every interaction both inside and outside the game (e.g., teacher scaffolding; Guardiola, 2016). This process allows educators to work with learners during playtesting to confirm that the game reinforces their intended behaviors, appropriately integrates and exposes learners to content, and does not inadvertently create unwanted emergent behaviors (see Grey et al., 2017). Although seemingly daunting, this step can be achieved by creating a simple flowchart during playtesting.

In order to create accurate, learner-focused gameplay loops, actually playing the game is crucial , preferably with a group of people who were *not* involved in the design process. This development stage is the perfect opportunity to, as suggested by research, explicitly include students as co-designers (Marklund & Alklind Taylor, 2016). This gives much more insight into the social and emotional flow of gameplay that cannot necessarily be discerned simply from reading the rules. Gameplay should be mapped at an overall level, with any sub-loops expanded as far as is useful. The gameplay loop (see Figure 2) is likely to highlight omissions, improvements, or opportunities that can be achieved by refining the game through iterative playtesting with learners and also identify any unforeseen issues that might arise for individual players. Note that, whilst formal testing is crucial, it falls outside the scope of this chapter.
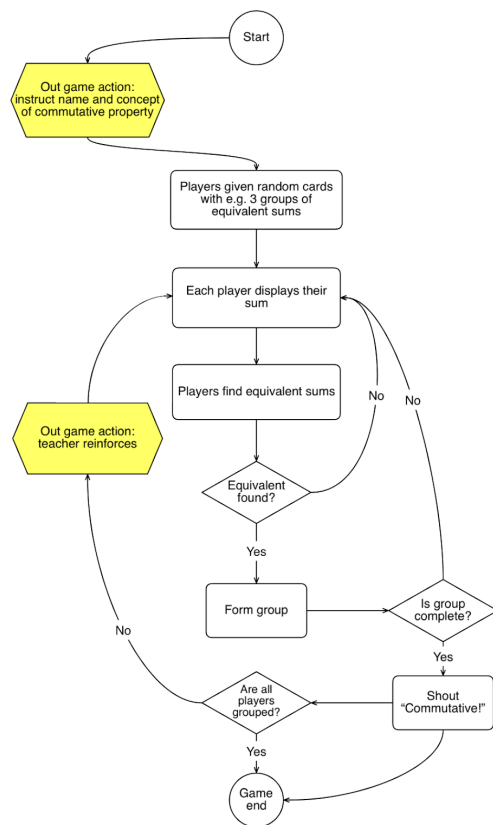
Figure 2

Gameplay Loop for Multiplication Game, Showing Out-Game Actions Which Link to the Wider LXD Context as Hexagons

3.9.1. Simple Example: Gameplay Loop Analysis

After a couple of playtests and her gameplay loop analysis (Figure 2), Maria realizes that she will still need to instruct the learners on what the commutative property actually is before they can engage in matching/grouping their sums. She wonders if this concept can be integrated into the game itself. Taking inspiration from another grouping game her class already likes (Animal Sounds), Maria creates a training round at the start of the game. In this game children are randomly assigned one of a few animals and they make the sound of their animal until all animals of the same type are grouped together. Maria realizes that, by combining this grouping behavior with the sum cards, she can encourage her pupils to actively make the connection themselves (e.g., all cats are equivalent to 3x5, all dogs are equivalent to 2x4). Doing so will not only make the learning more constructive but will remove the need for explicit instruction, placing the emphasis back on the learners.

Maria also decides to take the game outside wherever possible and introduces a new element, a chalk circle on the ground for each group containing the correct answer to each groups' sums. This means that players can find their group in two ways, either by an equivalent sum or by knowing the answer. This gives pupils the flexibility of a different pathway to understanding.

After several iterations checking her LMs, GMs, and gameplay, Maria moves the second ILO to the main game (i.e., it does not happen in the training rounds) and is happy with her final game (see Figure 3).

3.9.2. Extended Example: Gameplay Loop Analysis

Gameplay loops can be made even more rigorous by including the LMs and GMs in the loop for further insight (Abbott, 2019b). This helps to show which behaviors/interactions players are spending most of their time doing (or which are

side-lined) and can help GBL designers to centralize those learning behaviors defined as most useful.
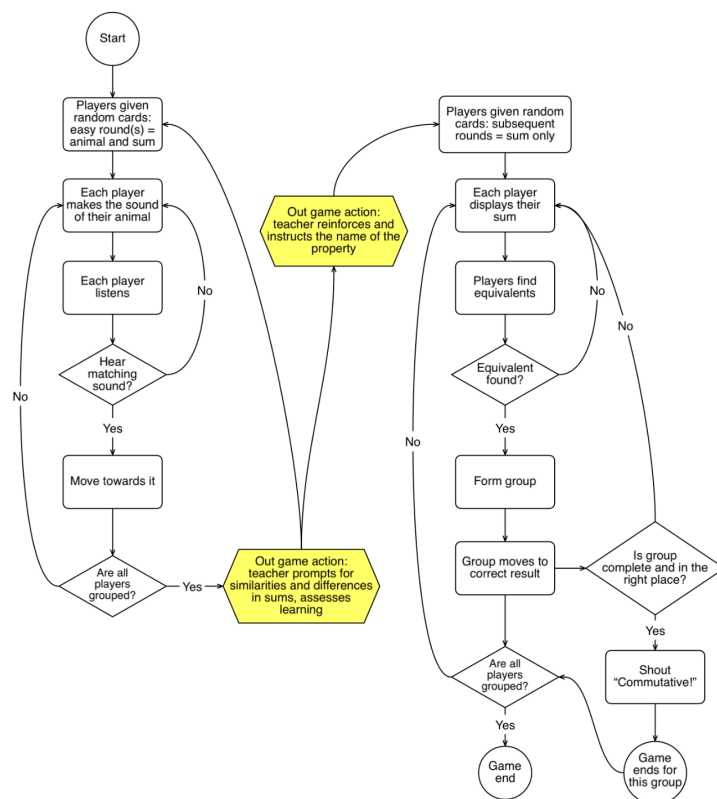
Figure 3

Final Gameplay Loop for Maria's Multiplication Game, Including the Training Round Based on Animal Sounds and Out-Game Actions

4. Conclusion and Reflection on the Workflow

The workflow and simple example presented here aims to guide readers towards increasing the rigour of their GBL interventions and to ensure that they benefit from a more explicit LXD approach. Educational games can be powerful personal learning tools with a focus on emotional flow as well as learner goals. As is clear from the literature, GBL often fails at this core objective due to being too much separated from both an appropriate pedagogical foundation and the needs and desires of the learners. LXD principles ensure this vital connection with learners can be maintained through the game design process.

By examining the interdisciplinary categories at each stage of the workflow, readers can identify where their own particular skills lie, establish any skill gaps that may need to be addressed in order to increase their overall expertise as GBL designers, and, for existing GBL practitioners, increase the focus on emotional design and the wider LXD context in which the workflow takes place. Admittedly, each stage may overlap with others as ideas are considered, and processes may be fuzzy rather than discrete. Whilst some may wish to follow the workflow step by step, others may already have an idea for learner-focussed GBL, in which case the workflow becomes a tool for validation of choices (and improving the rigour of the game design through subsequent iterations).

This chapter focuses on one small part of the overall LXD context (within the Interaction and Sensory planes) and has therefore not been able to discuss strategic, institutional, or practical considerations which impact game design within an LXD framework.

Finally, a widely experienced barrier for those integrating games into learning is resistance from colleagues or managers who may need to be convinced of the value of the GBL approach. In these cases, demonstrating the alignment of this GBL process with learner goals, desires, support-requirements, and enjoyment can help to elucidate the rigour and value of LX-centred GBL interventions.

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[1] Much more detail on this can be found in (Abbott, 2019a; Raybourn, 2016; Whitton, 2011) amongst many others.

[2] For more on learning effectiveness, efficiency, and achievement see Huang et al., 2019.

[3] For those readers already familiar and confident with educational game design, an ambitious and complex example involving four high-level, functional outcomes at postgraduate level is presented in the work of Abbott (2019b).

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LX Design-in-Use

This section consists of four chapters that relay cases of LX design-in-use. By design-in-use, we refer to the applied use of LX methods and processes to create digital environments for learning. These chapters serve as exemplars on multiple levels. On one level, they represent worked examples that detail the actions, events, rationales, challenges, etc. of LX design from beginning to end. On another level, the chapters are success cases of LX design, highlighting the synergistic interplay of pedagogy and theory with perceptions of usefulness and other hedonic aspects.

Integrating Learner and User Experience Design: A Bidirectional Approach

Participatory Design and Co-Design—The Case of a MOOC on Public Innovation

Supporting Equity in Schools: Using Visual Learning Analytics to Understand Learners' Classroom Experiences

Think-Aloud Observations to Improve Online Course Design: A Case Example and "How-to" Guide

Integrating Learner and User Experience Design: A Bidirectional Approach

Rebecca M. Quintana, Stephanie R. Haley, Nathan Magyar, & Yuanru Tan

Online Learning   User-centered Design   Learner-centered Design   Design Methods   Personas   Prototyping

As online learning experiences become more common in higher education, professional development, and lifelong learning contexts, the importance of understanding how learning experience design and user experience design intersect increases. In this chapter, we offer a vision for a bidirectional approach to learning design through the presentation of two design cases where both learning experience design and user experience design approaches inform the design of tools and designs for learning. We explicate two forms of bidirectional learning: (a) learning that occurs through academic partnership, which includes experiential learning and learning through groups and teams, and (b) learning through inquiry and through mental models. In this chapter, we present a working context that embodies these two forms of bidirectional learning, one that emphasizes shared activity and common projects, a joint working space, and prioritization of teamwork. This context fosters bidirectional learning across two disciplines, allowing team members in both disciplines to learn from each other and to develop shared practices and understanding of disciplinary approaches to design. We conclude with a list of guiding principles for learning experience design and user experience design collaborations.

1. Introduction

As online learning experiences become more common in higher education, professional development, and lifelong learning contexts, the importance of understanding how learning experience and user experience intersect increases. This emerging phenomenon invites interesting opportunities for Learning Experience Designers (LXDs) and User Experience Designers (UXDs) to exchange resources and methods and allows cross-disciplinary approaches to emerge. In this chapter, we offer a vision for a bidirectional approach to learning design through the presentation of two design cases (Boling, 2010; Smith & Boling, 2009) where both LX and UX approaches inform the design of tools and designs for learning. In our use of the term *bidirectional*, we draw inspiration from the global health literature, where the term is used to denote mutual, shared, and two-way learning. Redko et al. (2016) explicate two forms of bidirectional learning: (a) learning that occurs through academic partnership, which includes experiential learning and learning through groups and teams, and (b) learning through inquiry and through mental models. In this chapter, we present a working context that embodies these two forms of bidirectional learning, one that emphasizes shared activity and common projects, a joint working space, and prioritization of teamwork. This context fosters bidirectional learning across two disciplines (LX and UX), allowing team members in both disciplines to learn from each other and to develop shared practices and understanding of disciplinary approaches to design.

To elucidate the bidirectional working context, we begin with an account of the origins of learner-centered design and contrast it with user-centered design. Next, we explore how learner needs can motivate and guide a user experience (UX) design process, and we investigate how UX approaches can infuse LXD methods. In the first design case, we explore how learning experience (LX) considerations motivated the development of an online artifact sharing and feedback tool. In the second design case, we discuss how personas (a traditional UXD methodology) became part of one learning experience design team's toolkit for developing online learning experiences. We conclude with a list of guiding principles for LXD and UXD collaborations.

2. Theoretical Lens

An original goal of learner-centered design was to describe how technology-enhanced designs for learning require a specific perspective, one that is different from a UX focus on usability and task efficiency. Learner-centered design approaches draw on the principles of user-centered design and learning theory to create designs for educational technologies (Soloway et al., 1994). Historically, user-centered design approaches have put the user at the center, are concerned with supporting easy and efficient task completion, and provide understandable tools and interfaces so users can easily engage in a task (Norman, 1986). In user-centered design, the goal is to bridge the conceptual gap between the user and the tool (Norman, 1986). When designing for the learner, it is important to keep user-centered design goals in mind. However, when the learner is put at the center, additional objectives emerge, such as supporting and scaffolding learners to mindfully engage in activities that help meet learning objectives by motivating learners to complete a task, addressing the diversity of learner audiences, and accounting for the growing expertise of a learner (Soloway et al., 1994). Designers of learner-centered tools must also address the conceptual gap that lies between the learner and expertise embodied by experts (Quintana et al., 2001). Put another way, even if a software tool is designed effectively from a UX perspective (i.e., if the interface is easy for the learner to use) that does not necessarily mean that it is designed appropriately from an educational point of view, because learners need challenges, activities, and structures to support them as they engage with the educational software tool (Quintana et al., 2003; Squires & Preece, 1999). The distinction between a user and a learner is an important one, because, when designers focus on the user, they will naturally prioritize ease of use; when they focus on the learner, their goals shift to supporting learners to develop understanding, succeed in task performance, and increase expertise (Soloway et al., 1994).

One outcome of a learner-centered design approach is tools designed to facilitate the development of a learner's understanding of a new work practice or the "tasks, tools, artifacts, terminology, knowledge and relationships involved in a given work activity" (Quintana et al., 2001, p. 607). Learner-centered design is often premised on socio-constructivist views of learning (Fosnot & Perry, 2005; Palincsar, 1998), such as supporting learners in constructing and conversing about artifacts that are integral to a learning task. While much of the academic literature on learner-centered design has focused on developing software tools for use within educational contexts (e.g., Metcalf et al., 2000), learner-centered design may encompass learning within the workplace more broadly, such as when professionals develop their expertise in a domain (Soloway et al., 1994).

As designers adopt a learner-centered approach to design, UX and LX considerations must be held in balance; features of the tool should allow for efficiency within the operational task and be well-suited to the learning task (Squires & Preece, 1999). With respect to the operational task, designers must attend to how users interact with the tool and the support system that underlies the tool. The operational task may also comprise functional needs, information needs, activity needs, and management needs (Quintana et al., 2003). Learners may require access to additional software (functional needs), information that experts use in their work (information needs), and explicit representations of activities that are implicit within authentic work environments (activity needs). Learners may also require support for managing and accessing artifacts and materials that are required to complete the learning activity (management needs). In regards to the learning task, designers must also concern themselves with issues such as whether the tool promotes the development of skills and concepts that are integral to a particular topic of study (Squires & Preece, 1999). The learning task is related to a learner's cognitive activity and can include process management, sensemaking, and reflection (Quintana et al., 2004). Learners may need support for navigating through work processes and activities

that are specific to a subject domain (process management). They may also need support for analyzing and making sense of their work products, such as through the provision of a graphic organizer (sensemaking). Learners may require support to express an understanding of their work to themselves, peers, or their instructors (reflection). These forms of support, both for operational and learning tasks, can be understood as scaffolding (Quintana et al., 2004). Scaffolds allow learners to complete otherwise inaccessible cognitive tasks through the design and incorporation of particular features and tools. To understand learner needs when designing tools for learning, designers should embark on an iterative process that requires them to understand the learning objectives, the learning context, and the underlying practice of the domain (Quintana et al., 2003). These steps will allow designers to identify the supports that learners will need to complete the learning task and to design the scaffolding features that will best support learners.

With respect to evaluating the usability of a digital interface, Jakob Nielsen's heuristics are one approach to follow (Nielsen, 1994). However, not all of these heuristics are directly relevant to an educational context; thus, they require an integrated approach, one that does not artificially separate usability and learning considerations (Zaharias et al., 2002). Squires and Preece (1999) adapt the idea of usability heuristics and construct a set of "learning with software" heuristics, which incorporate a socio-constructivist view of learning (Palincsar, 1998). These include (a) congruence between designer and learner models, in which the design supports the evolution of the learner's model of the target domain; (b) requirement for navigational fidelity, in which representations should neither oversimplify nor overcomplicate a learning task; (c) need to consider appropriate levels of learner control, in which learners are given an appropriate level of control within a supportive environment; (d) prevention of peripheral cognitive errors, in which any learner errors are relevant to learning tasks and not operational tasks; (e) understandable and meaningful symbolic representation, in which the use of symbols and representational forms are consistent; (f) support personally significant approaches to learning, in which learners receive support materials and aids for metacognition; (g) strategies for cognitive error recognition, diagnosis, and recovery cycle; and (h) alignment with curriculum, in which tool design moves learners towards the achievement of specific learning goals that are specified in advance. In what follows, we explore two design cases that feature a learner-centered approach to design, with distinct contributions from LX and UX perspectives.

3. The Gallery Tool

3.1. The Problem

Today's learning management systems (LMS) offer a variety of features that allow designers to create rich educational environments. However, these capabilities are not always well-suited for constructing an experience that will allow learners to succeed in a learning task. As a result, instructional teams must often work within the constraints of the LMS features available to them (Najafi et al., 2015).

At the Center for Academic Innovation at the University of Michigan, LXDs partner with faculty to design learner-centered, research-informed online learning experiences. They also observe and identify limitations learners face when interacting with online course delivery platforms, including: (a) inefficient exchanges within asynchronous peer feedback systems (i.e., on peer-graded assignments) and (b) online discussion forums that present major usability challenges.

Given these observations, LXDs identified a major problem—learners lacked a way to easily share artifacts that reflect their understanding with peers and to receive feedback on them. Ideally, a digital solution to this problem would:

- Integrate seamlessly with any online learning platform.
- Allow learners to share work with peers and receive timely feedback.
- Structure a peer feedback process that elicits high-quality interactions.

To realize this idea, the LXD team collaborated with the "Online Tools Team", a group of experts in user experience, software development, and behavioral science who aim to enhance the school's online learning opportunities. The

result of their work was the Gallery Tool, a content-agnostic tool that facilitates sharing of coursework and peer feedback (Park & Quintana, 2019).

3.2. The Process

3.2.1. Project Scoping

The Online Tools Team started by interviewing LXDs that had expressed concerns about an online course delivery platforms' existing functionality. Like other informational interviews, these conversations framed and scoped the problem and collected feature requests. However, unlike typical informational interviews, these discussions aimed to uncover ways of supporting learners' reflections on artifacts produced during assignment creation and not simply increase the technology's ease of use.

Next, LXDs identified two online courses which would guide the design of the tool; one course focused on writing and the other on programming. These courses were selected because they contained assignments that were well-suited to peer sharing and feedback. With these courses in mind, the group determined features for the minimum viable product (MVP), the most basic set of features the tool needed. In doing so, LXDs also considered each feature from the perspective of the learning task. If a feature conflicted with the project's ultimate goal of sharing work and receiving feedback, it was excluded. For instance, gallery submissions could have been displayed from most to least viewed, but LXDs felt this might cause an uneven distribution of learners' attention in the gallery. Thus, a sorting algorithm was developed to elevate submissions that most needed feedback to the top of the page.

3.2.2. Competitive Analysis

To confirm that an identical tool did not already exist, the UXD performed a competitive analysis of five digital peer feedback products. The UXD evaluated competitors according to learner-centered criteria, including:

1. Existence of any peer feedback scaffolding, likely in the form of instructions authored by an instructional team.
2. Seamless LMS integration, to avoid learners having to create another account for a separate platform.
3. Support for learners to upload different types of media (e.g., text, graphics, audio files, and links).

The UXD discovered that a range of peer feedback scaffolding existed among competitors: some offered none at all, others provided robust customization of instructions. Regarding integration, most products required that users create a separate account. And in terms of upload support, some offered only one type (e.g., video), and others allowed for several formats (e.g., videos, text, images, and links). Ultimately, no tool existed that perfectly met all of the team's needs.

3.2.3. Sketch and Wireframe

Before sketching the tool's interface, the UXD mapped the MVP features onto corresponding proposed pages within the tool and shared these groupings with LXDs (see Figure 1).
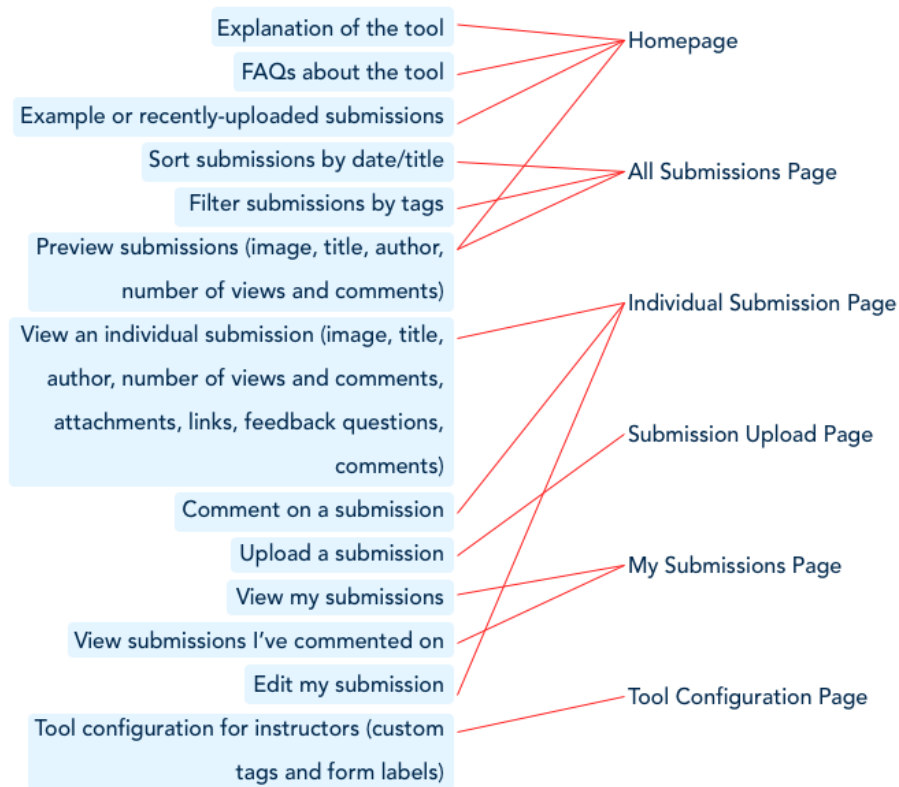
Figure 1

Feature Map

Note. To ensure that each MVP feature had a place in the tool and that everyone agreed on its general architecture, the UXD associated each feature with its intended page. This map also supported the sketching phase of the process as it provided a clear set of requirements the design had to meet.

Next, the UXD created sketches (see Figure 2) to experiment with page layouts and content structures. These were also shared out for feedback.
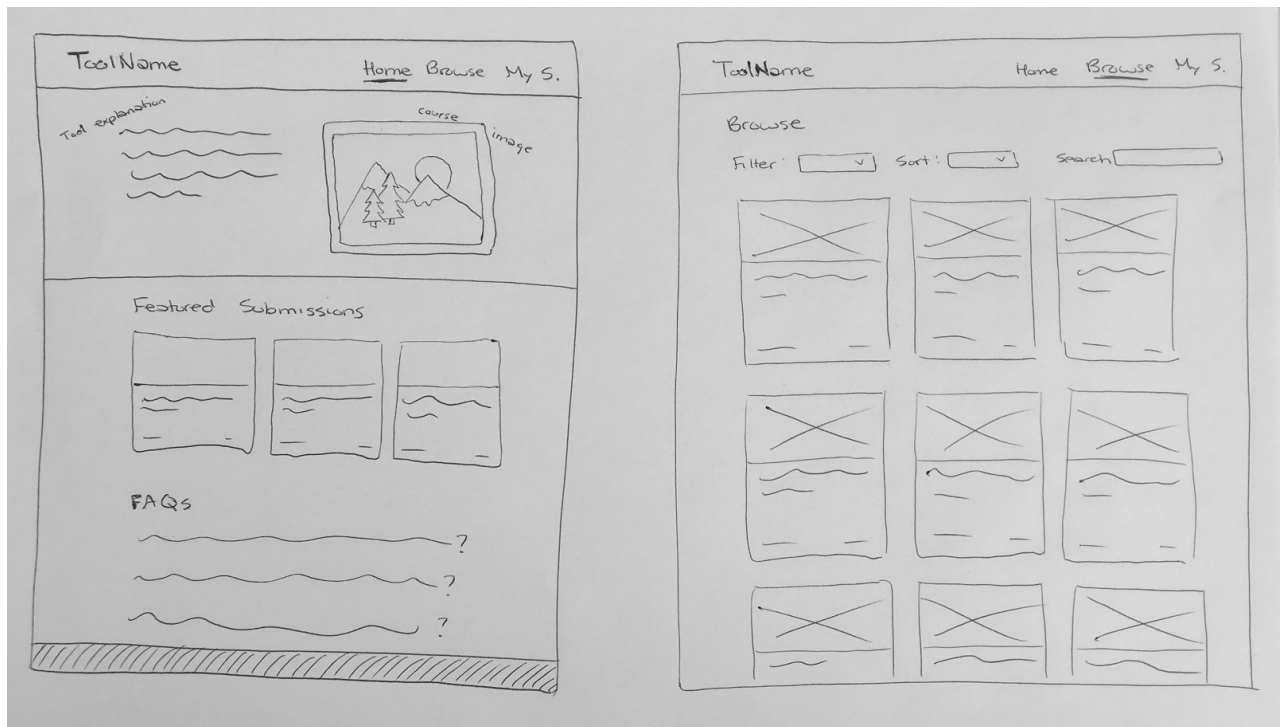
Figure 2

Preliminary Interface Sketches

Note. The preliminary sketches were intentionally drawn with paper and pencil to enable quick and easy changes to the design as feedback was collected from the team.

The UXD then selected a color palette and typeface and created a user interface (UI) kit (see Figure 3).
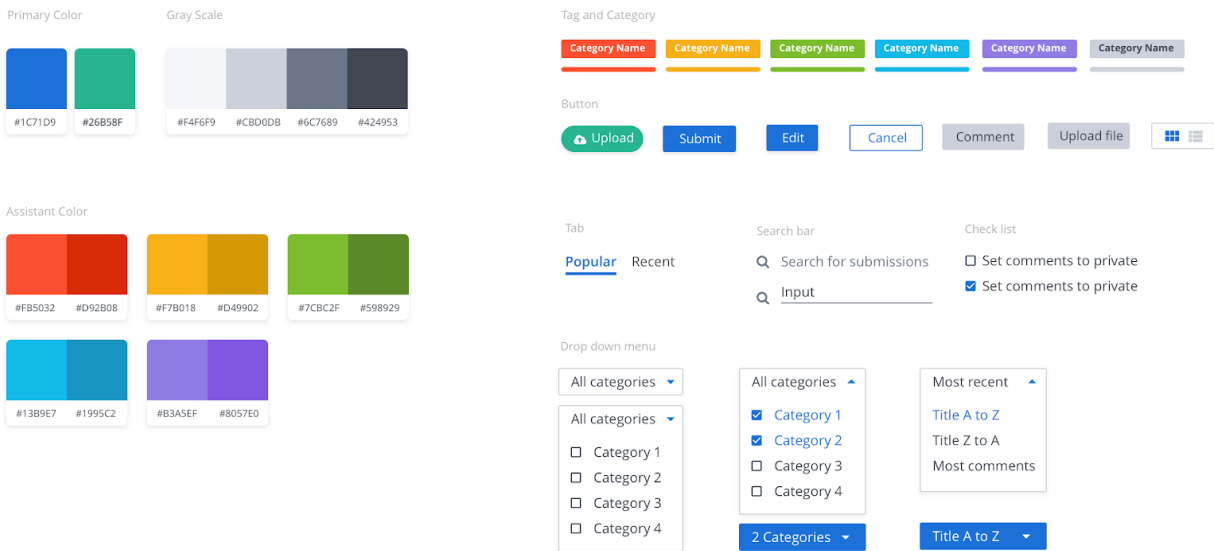
Figure 3

UI Kit

Note. The UI kit is a collection of various interface components that can be reused throughout a digital product, such as buttons and form input field styles (right). Kits also commonly define the color palette (left).

Finally, the UXD created realistic mock-ups (see Figure 4) using the UI kit.
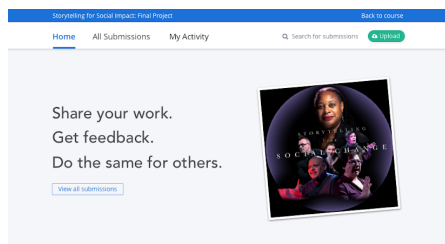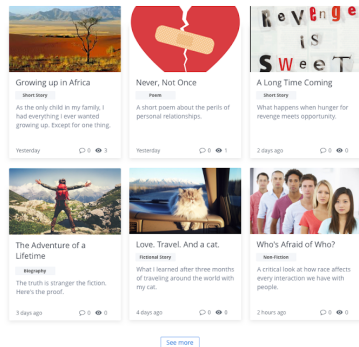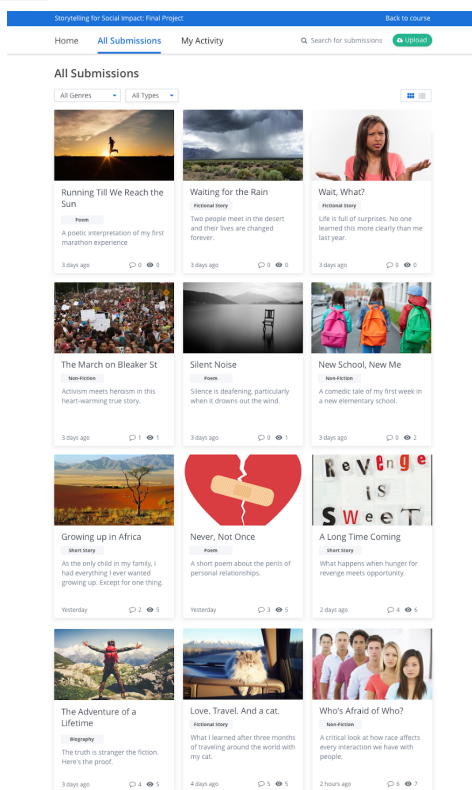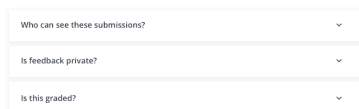
Figure 4

Note. Realistic mock-ups are an important phase in the design cycle, as they help to clarify the overall direction of a project, elicit additional feedback from stakeholders, and prepare for usability testing.

3.2.4. Software Testing: Usability and Learning

Guided by Squires and Preece's (1999) eight software for learning heuristics, the team had several objectives when usability testing the mock-ups:

1. Identify where the design was confusing to learners (i.e., ensuring "prevention of peripheral cognitive errors" which are not productive for the learning task).
2. Confirm learners were satisfied with the tool's functionality (i.e., providing appropriate "learner control").
3. Ensure the tool's information architecture made sense for use within an online course (i.e., fulfilling the "requirement for navigational fidelity").

To prepare for the tests, the UXD drafted a protocol of realistic tasks. She wrote instructions in a non-leading way to elicit the most natural behavior from learners possible. For example, instead of directing learners to "click the upload button," she asked them to "find a way to add a new submission." The user experience researcher (UXR) then recruited 15 college-age learners with previous online learning experience to participate in a 30 minute test. After using the protocol to run the tests, the UXR summarized her findings: learners thought the tool was easy to use overall but suggested improvements, such as different wording for navigation items and more advanced searching options.

3.2.5. Implementation

Both the backend developer and the UX designer contributed in the implementation phase. Two design requirements of the backend developer were used, the Learning Tools Interoperability (LTI) standard, so that the tool could be used in any LMS that supported LTI (e.g., Canvas, Coursera, and edX) and customizable data model fields so that instructors could modify the tool to suit their learning context. Two weeks later, the Gallery Tool was ready for use.

3.2.6. Usage Data Collection and Analysis

Seven months after releasing the tool, the UXD collected basic usage statistics from the programming course gallery. Since the tool's launch, 13% of learners uploaded a submission. She also found that not all those who uploaded work also provided feedback to others. Moving forward, the team plans to interview learners to identify areas where the tool could be improved.

3.2.7. The Final Product

The following video, Gallery Tool Demonstration, offers a live tour of the Gallery Tool.

4. Asynchronous Persona Creation Activity

4.1. The Problem

While important in many design contexts, the heterogeneity of learners is especially important to consider in learner-centered design (Quintana et al., 2001). Learners cannot be assumed to possess a common body of expertise and thus may approach a task with varying levels of understanding and experience. Within the context of online learning environments, learners may be varied in terms of demographic characteristics and bring a diverse range of educational backgrounds and personal goals (Levick et al., 2017; Littlejohn et al., 2016). As a result, instructional teams are tasked with designing for an "unknown learner" (Macleod et al., 2016). Another challenge is that online courses must be designed in advance of launch, requiring instructors to define instructional materials with little ability to make changes once a course is live.

In this design case, we describe how a well-known approach within UX design processes (personas) was adopted by LXDs and used within educational design processes (learner personas). LXDs needed a means of describing a learner audience's online learning experiences, even in advance of course launch. Personas are fictional representations of potential users that can be used at critical junctions in a design process, such as when a feature decision needs to be made (Goodwin, 2002; Pruitt & Adlin, 2010). Personas "encapsulate and explain critical behavioral data in a way that designers can understand, remember, and relate to" (Goodwin, 2009, p. 229) and create focus when design teams may have vague or contradictory ideas about who they are designing for (Cooper, 2004). A further benefit is that personas offer a shared means of communication for stakeholders throughout the design process (Cooper, 2004). While learner-centered design practitioners create learning experiences that are premised on an understanding of how people learn, they have not typically relied on learner personas as a methodology in the design process.

4.2. The Process

4.2.1. Context

To help instructional teams understand the target audience for an online course, LXDs developed the Asynchronous Persona Creation Activity, which included a persona creation and reflection component. We describe a typical enactment of the activity, which has been used with multiple instructional teams. Through this activity, LXDs aimed to achieve two objectives:

- Sketch out characteristics of representative types of learners, such as demographic information, previous domain knowledge, and motivation for enrolling in a course.
- Establish a shared referent of a prototypical learner to support future design decision making, including defining learning outcomes, setting the "rigor" level of a course, and creating activities and assessments that are aligned with course objectives.

4.2.2. Activity Design

LXDs provided faculty with an online slide deck that consisted of three sections:

- Introduction to the concept of learner personas, definitions of three types of learner personas, and an explanation of how using this approach can be used within a learner-centered design process.
- Exemplar personas.
- Resources needed to create personas, including links to a name generator website and open license profile photos.

LXDs provided faculty innovators with an overview of three types of learner personas: assumptive, aspirational, and data-informed (Quintana et al., 2017). An assumptive persona is based on an instructor's experience of what a learner typically "looks" like in a course including their interests and values. This representation is oftentimes based on a faculty member's experience teaching in a residential setting. An aspirational persona is based on an instructor's goals for attracting a certain type of learner to their course. For example, an instructor may desire to engage women in computer science courses. Data-informed personas are based on learner data such as survey data and interview data and shed light on potential learners' demographic characteristics, motivation, and background knowledge.

LXDs provided instructors with guidelines and exemplars for creating assumptive and aspirational personas. LXDs included reflective prompts for building assumptive personas such as: "Pause for a moment and think about a typical student in your residential course (or a type of learner that you would like to attract to your course): What are their goals for taking the course? What are their strengths? Where do they struggle? What motivates them? What kinds of activities and experiences do they find engaging?" Instructors could also choose to build an aspirational persona if they had a particular type of learner in mind.

LXDs included a learner persona template (to be used for either assumptive of aspirational personas), which consisted of five categories:

- Demographic information (age, profession, and education background).
- Current knowledge about the course topic.
- Motivations for taking the course.
- Engagement strategies for participation in the course (e.g. planned time commitment)
- Fictional self-introduction quote from the persona's point of view.

Instructors developed personas asynchronously (i.e., in advance of a group meeting) by interacting with the informational content and step-by-step instructions in the slide deck. Once an instructor finished the persona creation activity, the instructional team met in person and moved to the final phase of the Asynchronous Persona Creation Activity: discussion of learner personas based on the five informational categories and reflection on the persona creation process. Through discussion, the instructional team reached consensus on the target audience for the course and defined a shared referent for future design decision-making. We provide an overview of the Asynchronous Persona Creation Activity in Figure 5.
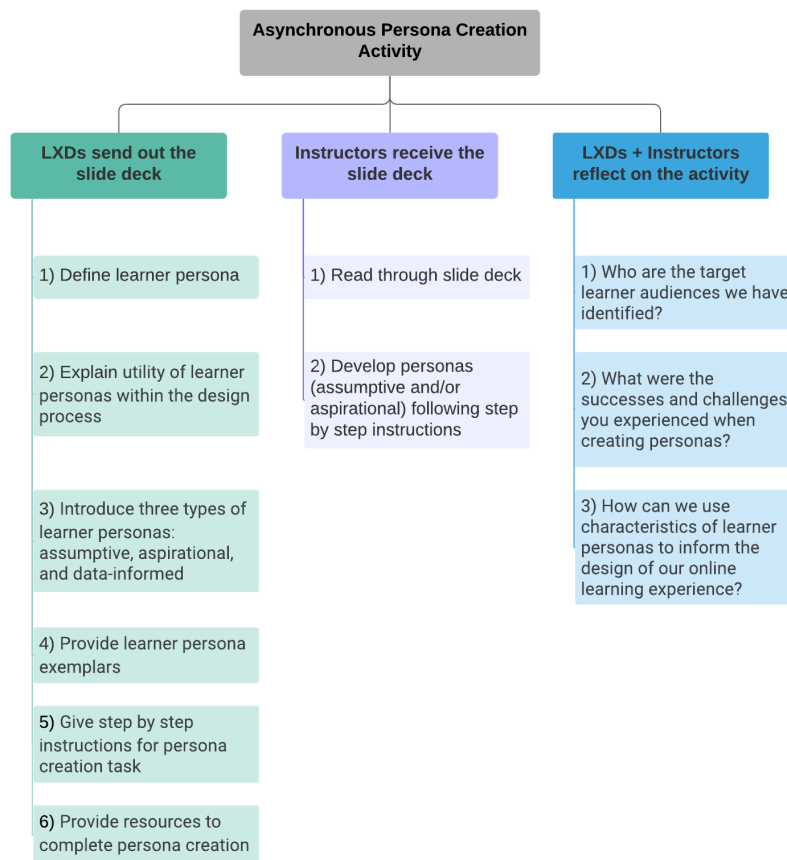
Figure 5

An Overview of the Asynchronous Persona Creation Activity

4.3 Outcomes

Outcomes of the Asynchronous Persona Creation Activity included one or more learner personas representing the target audiences of the course. The example below (Figure 6) depicts an assumptive persona for an augmented reality online course. The persona's name (Stacy Herrera) was generated using an online name generator and the profile photo was selected from open license online images. Other information such as content knowledge, motivation for taking the course, and engagement strategies were provided by faculty who had experience teaching a course about augmented reality to students in a residential university setting.
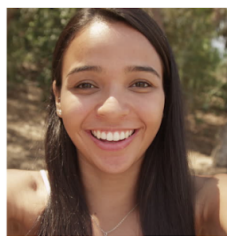
Stacy Herrera

High school history teacher
29 years old

Educational Overview
New Jersey Certificate of Teaching
B.A. in Education

💬 Quote / Summary

Stacy teaches history in a high school and she loves trying out how different technologies would work in her history classroom. After experimenting with several AR applications in classroom activities, Stacy was pleased to see students' excitement about AR, but also wonders if she is using the technology to its best advantage.

"I kinda know what AVMR is and it's a quite intriguing topic for me. I'd like to learn more to hopefully be able to apply AVMR in my teaching in a smart way."

🏛 Content Knowledge

- Knows the concept of AVMR in general

- Has experience doing several AR activities in classroom, such as Civilisations AR, Expeditions

- Participated in several professional development workshops and webinars about using AR in classroom activities

◎ Motivation for Taking Course

- Become more knowledgeable about AVMR, especially about pros and cons of application in education

- Become more confident about applying AVMR in classroom activities

- Gain some ideas about how other teachers use AVMR technologies in their classrooms

🖥 Engagement Strategies

- Proficient in using online learning platforms

- Is highly motivated to complete the specialization; would like to get a certificate for this specialization to add to her LinkedIn profile page

Figure 6

An Example of an Assumptive Persona Created During an Asynchronous Persona Creation Activity

5. Guiding Principles for LX/UX Collaborations

Early in the process of creating the Gallery Tool, the LXD team observed a key difference between learner-centered design and user-centered design: in the former, development of domain knowledge in learners is the primary objective; in the latter, users' ability to easily and efficiently complete a task within the system is of utmost importance (Quintana et al., 2000). That does not mean, however, that usability holds decreased significance in learner-centered design. In fact, it is quite the opposite. Educational technology should be so easy to use that a learner is less focused on learning the system and more concerned with learning the material (Zaharias et al., 2002). Therefore, it is important to clearly articulate and understand the learning objectives and scaffolding needs for learners surrounding an educational technology tool. With that knowledge, features developed for the technology serve, rather than contradict, those goals.

Our two design cases reveal that LXDs and UXDs must consider both learner and user needs when designing an online course or tools for education. Understanding the importance of learner-centered design is beneficial for UXDs working on projects similar to the Gallery Tool. Using that understanding, UXDs can elicit responses from LXDs about what kind of tasks will engage the learner and what makes those tasks challenging.

This shared understanding is also key to the success of integrating UX approaches into the learning design process. Many instructors are not familiar with traditional UX tools such as personas. LXDs can educate instructional teams about the benefits of using specific UX methodologies like learner personas in the design process. If teams are not explicit about these benefits, instructors could resist methods that are intended to support the design of learning experiences because they are unclear about their purpose.

When incorporating new UX tools into a learning design process, opportunities for reflection provide instructors time to think about their learners and educational design in new ways. The asynchronous nature of our persona activity provided necessary space and time for instructors to reflect on their own understanding of potential learner audiences before bringing the learner personas into a larger group discussion.

In summary, we offer the following guiding principles for LX/UX collaborations:

1. LXDs should clearly articulate learning objectives and scaffolding needs for learners surrounding an educational technology tool prior to design.
2. Both LXDs and UXDs should develop a shared foundational understanding of learner-centered and user-centered design.
3. UXDs should communicate goals and advantages of using any particular UX tool or methodology in the learning design process.
4. LXDs should provide opportunities for reflection within the instructional design process when incorporating new UX approaches.

The case studies above offer several implications for LXDs, UXDs, and researchers. They also reveal additional opportunities for continued bidirectional research at the intersection of LX and UX. This bidirectional approach provides a shared language and a subset of practices to be held in common by LXDs and UXDs. The potential for missed opportunities is increased when LX and UX design remain partitioned. By developing a shared set of practices, there will be greater opportunity to discover how bidirectional approaches can improve the design of educational tools and learning experiences. In a future where career paths and trajectories require lifelong learning (often through the use of new technologies), the collaboration of these disciplines through shared language and practices remains important. Furthermore, there has been a growing interest in developing shared understandings among academics who focus on human-computer interaction approaches and those whose practices are rooted in the learning sciences (Ahn & Clegg, 2017).

We see potential for expanding this bidirectional approach to research collaborations, with opportunities emerging for UX and LX researchers to engage in joint research projects. We believe the products of these research collaborations will be of interest to researchers in the learning sciences and human-computer interaction. As LX and UX designers prepare conference proposals and journal manuscripts for learning sciences and human-computer interaction conferences and journals, they will engage in disciplinary and academic boundary crossing, exemplifying the shared practices and nuanced understanding of disciplinary approaches to design that have been cultivated through a bidirectional approach to learning. We hope that as LX and UX designers consider approaches beyond their own immediate disciplines that new opportunities for innovation will arise, enrich the design process, and improve design outcomes.

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Participatory Design and Co-Design—The Case of a MOOC on Public Innovation

Dorothée Cavignaux-Bros & Denis Cristol

Professional Development MOOC Co-design Participatory Design Learner Experience Design

Public Innovation

Today, a large body of knowledge exists on Instructional Design, for practitioners as well as for researchers working in Adult Education and Training. However, historical models used for the design of training do not seem to be effective enough in the context of digitalization or multi- and transdisciplinarity. Other fields of research can provide more comprehensive approaches in analyzing the key factor success of training design. In this chapter, we focus on a design case (Howard, 2011) in the field of adult vocational training in France, showing how mix methodologies using participatory design and co-design processes were used to engineer a connectivist Massive Open Online Course (MOOC) (Siemens, 2005). Its purpose is to show how participatory design can be used to design a MOOC and to expose its limits and underlying dimensions.

1. Introduction

The currently vast body of knowledge on instructional design (9907 publications on July 28th, 2019, among ERIC's peer reviewed results) shows how designing education and training has been influenced by the evolution of industrial design, Information and Communications Technology (ICT) developments, and learning theories, such as behaviorism to andragogy, connectivism, socio-cognitivism or other findings in Educational and Training Sciences. Furthermore, learning labs, makerspaces, third places (Oldenburg, 1989), and the import of User Experience Design (UXD) in Educational and Training Sciences are changing the way education and training are designed and produced. We are entering into a "learnance" era (Cristol, 2014, p.13). At last, design thinking and other design methods from design sciences are also being used to address more complex projects like multimodal training programs.

In this chapter, we focus on a design case (Howard, 2011) in the field of adult vocational training in France that demonstrated how a mixed methodology of participatory design and co-design processes were used to engineer a connectivist MOOC. In this context, connectivism is defined as "the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements—not entirely under the control of the individual" (Siemens, 2005). Connectivism's purpose is to show how participatory design can be used to design a MOOC and to expose its limits and underlying dimensions.

2. Theoretical Lens and Context of the Case

2.1. Participatory, Design Thinking and Co-Design

Participatory design was first defined in Scandinavian literature "as a model for involving users and designers on the technology itself in a process of technological development" (Asaro, 2000, p. 257). Participatory design implicitly and explicitly intends to create artifacts while transforming people collectively by taking into account other's perspectives (Könings et al., 2014).

Design thinking was used by Tim Brown from the IDEO agency (2008) as "a discipline that uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (p. 2).

In this chapter, *co-design* refers to "the creativity of designers and people not trained in design working together in the design development process" (Sanders & Stappers, 2008, p. 6). Co-design is collaborative by mixing together designers, users, novices, experts, citizens, or customers with the assumption that anybody is an expert regarding their own experience and mobilizes their practical and experiential knowledge as well as their conceptual knowledge.

2.2. MOOCs

Since their first mention in 2008 and their deployment in France in 2012 (Cisel & Bruillard, 2013), Massive Open Online Courses (MOOCs) have gained in visibility. While the concept has recently been very successful, distance education has more than 20 year history focusing on online learning through videos, forums, and storytelling (Dieumegard & Durand, 2005). What appears to have changed since the first MOOCs is:

- The fluidity and reliability of multimedia technologies,
- A continuing expansion of professional as well as private means of communication (smartphones, computers, tablets),
- Free and easy access to online resources,
- The increasing digital literacy of learners,
- The development of a culture of learning, making everyone responsible and actor of their own learning,
- The generalization of a diversified offer of online and free training by large public operators.

2.3. Context of the Case: A Strategic Project for Change Management in a Training Institution

The Centre National de la Fonction Publique Territoriale (CNFPT), subsequently referred to as *the Institution*, is a French organization dedicated to workplace training of local administration staff. It has a hundred sites all over France and trained 920,000 adults in 2018, implementing more than 68,000 training sessions. 196,000 users registered on the online platform, and 37,000 participants joined webinars in 2018. Its workforce counts 2,392 permanent jobholders including project managers and training consultants that design and organize the training sessions. Trainers are mostly specialists or subject matter experts working in public administrations, external trainers, and consultants. Training consultants working inside the organization sometimes participate in the training as (co-)facilitators during both online and face-to-face sessions.

A few years ago, the Institution decided to transform its activities by introducing what they called "co-design." The main objectives were to develop collaborative learning to accelerate the use of digital tools in both face-to-face and distance learning and to modernize their range of services, including developing a blended learning offer. Collaborative learning was intended to engage participants through addressing real situations and facing challenges together (Dillenbourg et al., in Spada & Reiman, 1995). During this process, online communities emerged along with the opening of a learning lab and co-design rooms.

To facilitate the process (change management), immersion in participatory design and co-design sessions were organized with external consultants (at least two external firms and freelancers). During the first year, one to two training consultants and project managers from seven different implementation sites were identified as expected early-adopters of the project and the method. These early-adopters were placed in charge of training others and facilitating the spread of new practices. Co-design was implemented in dedicated training rooms or co-working spaces like a learning lab equipped with technologies to collaborate and craft material (e.g., Lego bricks, paper, pieces of fabrics, etc.) to stimulate creativity and prototyping (non-technological). The project itself took two to three years to be implemented. The development of co-design methods was progressive, iterative, and linked to the installation of the co-design rooms. Both participatory design and co-design (Figure 1) were used during those training sessions (Sanders & Stappers, 2008, 2014). The learning artifacts and instruments created during these sessions were training scenarios, storyboards for videos, quizzes, programs, MOOC frameworks, etc. For instance, Personal Learning Environments (PLE) were prototyped during a 3 hours co-design workshop; a participatory design session involving learners, experts, and trainers was used to transform a training program on laïcity.
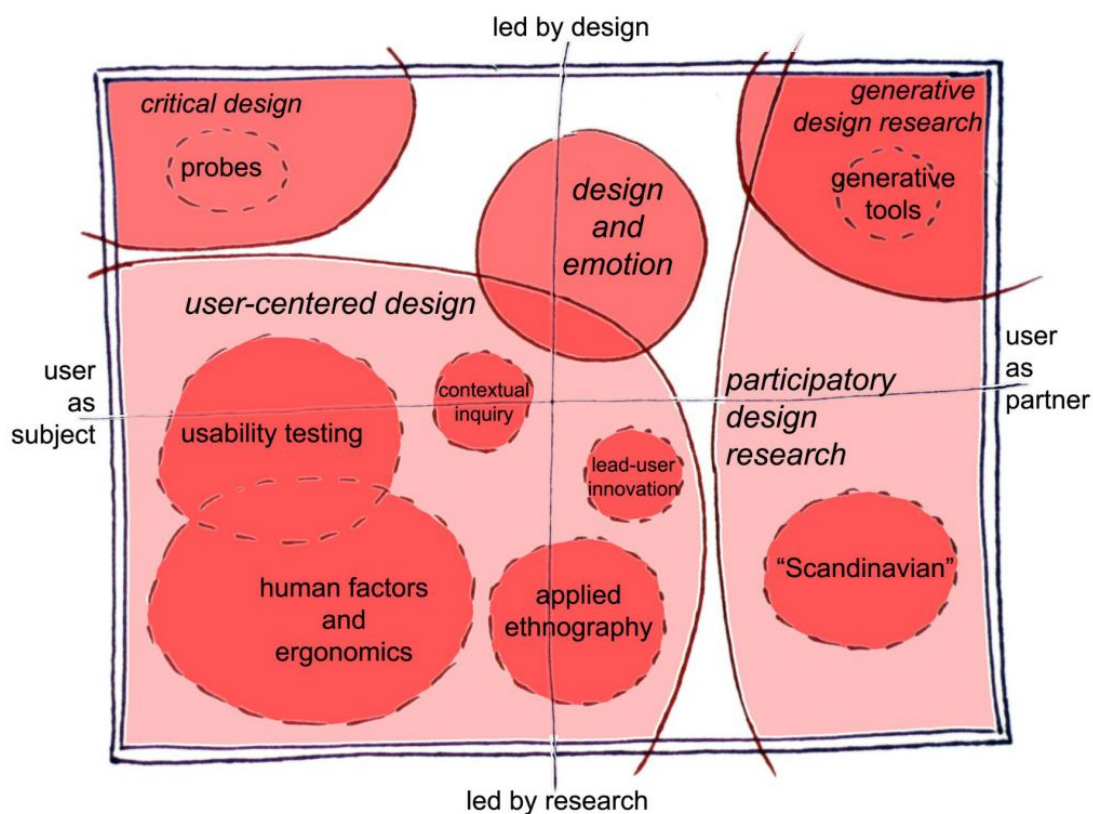
Figure 1

The Current Landscape of Human-Centered Design Research as Practiced in the Design and Development of Products and Services

Note. From Sanders & Stappers (2008, p. 6).

In addition, the authors of this chapter were involved in this design process. The authors are a researcher working in the Institution and a part-time PhD student working outside the Institution. The PhD student spent two years, during the first phase of the project, observing and participating in co-design sessions[1] of public services or training resources with an ethnographic approach.

The main challenge the Institution faced was preparing the second edition of a summer seminar dedicated to innovation and co-design called the University of Public Innovation. During preparatory workshops came the idea of designing a MOOC on public innovation in a collaborative way.

2.4. A MOOC Project Based on Collaborative Learning: Toward a New Generation of MOOCs in the Institution (Basic Assumptions)

Because of their previous MOOC experience, the Institution became a central management hub of territorial and professional physical networks (inter-regional seminar, roadmap seminars, seminar speakers, co-design seminar) as well as digital networks (structuring and managing around thirty professional online communities). The Institution uses its own online platform based on a strategic and well-established partnership with FUN[2] (a French Institutional MOOC Platform). In addition, the Institution applies a digital strategy including documentary, technical and educational resources and tools, a support team, and recently a multimedia-recording studio. MOOCs in the institution are built on co-learning to benefit the Institution's mostly autonomous learners and engineering teams. As a result of receiving less public money, the Institution shifted from distributing knowledge, with all the design costs that entails, to co-building knowledge with professionals and helping them engage with their territory (Inghilterra, 2016).

The Institution's engineering team researched the market's MOOC methodology; they found: a) MOOCs suffer a significant attrition rate (more than 90%), b) most of the market-offered MOOCs were carried out in parallel with traditional educational activities, and c) learners were mostly isolated and sometimes engaged in few collaborative activities. As a result of their research, the engineering team envisioned a MOOC based on collaborative learning and social learning to foster commitment (Bandura, 1997).

Building MOOCs around online collaborative learning had the advantage of being more focused on motivations and teaching dynamics than just simply on content. Another benefit was that the online platform provided the Institution's existing pedagogical know-how a broader range of influence in the local community. As a result, the MOOC would weave and strengthen links with local actors through the recommended real life connections.It would allow the emergence of new teaching formats (Conole, 2013), school communities, and learning visits as well as peer sharing or professional co-development groups. These new generations of MOOCs could combine the training institution's distinctive strengths of national presence and local networking with its capacity to create digital learning paths. Indeed, this would increase training transfer into working situations by focusing on the concrete projects of the participants.

Learners would benefit from peer learning, the territorial frameworks, and sharing operational projects. Promoting online collaborative learning through online communities could foster the creation of a personal learning environment (Dessus et al., 2011; Duplàa & Talaat, 2011), reinforce the desire to learn by oneself, and encourage a culture of self-directed-learning (SDL). Focusing on learning how to learn would be transposable to all activities of the territorial framework. More than simple interactions with online content, the MOOC's hybridization of face-to-face and distance learning would enhance collaborative learning and create local clusters. This collaborative dimension would be another benefit. In such cases the teams would need to learn how to collaborate better.

Though the accessibility of MOOCs embodies the learning principle "When and where I want it", MOOCs struggle to maintain long term commitment from their remote participants. Collaborative learning within a MOOC offers benefits that can mitigate this shortcoming. One benefit was the opportunity to learn from a stronger support for learners to carry out their individual projects. Another benefit was, when the collaborative learning format was inserted in other pedagogical activities, that users derived more personal significance and experienced greater personal motivation (Kennedy & Laurillard, 2019).

3. The Co-Design of the MOOC: Process and Means

After the first edition of the Summer University of Innovation organized by the Institution in 2016, its sponsors decided to enlarge participation and find new ways to prepare participants. Simultaneously, the Institution was implementing co-

design as a new strategy to foster collaboration and the professional development of its staff in instructional design.

3.1. Emergence of the MOOC and Timeline of the Project

The idea of a MOOC on public innovation was born from an opportunity to study connectivism in MOOCs and the urgent need to prepare innovators by giving them methods and strategic tools to become actors and even translators in the process of implementing the next universities. The principles of the actor-network theory and the concept of translation were applied (Alkrich et al., 2006).

A group of 8 to 10 persons working in different entities of the Institution started to team up, based on voluntary basis. The design team, as seen in the timeline below (left side column of Figure 2) evolved from a working team to a participatory team. The team used design thinking, co-design, and participatory design to define the MOOC architecture (central column of figure 2) in an iterative approach (right side column of Figure 2).

3000 participants	First MOOC session	• Implementing the two learning routes prototyped in July	May n+1
Design team + declared and potentiel users (random)	Participatory and co-design during the July University of Innovation	• Test of a the first prototype • Co-design of a second prototype • Users testing	July n
Design team + self declared users and sponsors	Intermediary Co-design session : Macro design of the MOOC	• architecture of a connectivist mooc (first prototype)	June n
Mixed Design team	Preparation of the July participatory and co-design session	• Production of a video teaser • Preparation on what to prototype during the university	May n
Work team	Analysis phase	• Co-construction of the MOOC using design thinking	March n
University of innovation sponsors	Intention note	• Opportunity note on participatory MOOC • Literature review on connectivist MOOCs	October n-1

Figure 2

Timeline of the Co-Design of the MOOC from October 2016 to May 2018

The MOOC was designed using different methods of instructional design and project management. From a macro perspective (Desjeux, 2004), the project was led by an iterative and test-and-learn approach. It was sponsored by the Learning Lab team and was part of the participatory design of the second edition of the University of Innovation. On a meso scale, the architecture of the MOOC was built using an instructional co-design process. On a micro scale, participants in the process could be members of the design team (external consultant and an internal work team), self-declared users, and/or sponsors of the project who volunteered to participate in the co-designing of the architecture. Participants came from the University of Innovation and other participants from outside the university.

The first collaborative design session was held in March, during an in-house action-training seminar using co-design to work on various digitalization projects. A team of 8 persons participated in a collaborative workshop to identify the target learners of the MOOC, to choose the pedagogical format, and to organize the design project team. The objective was to prepare the co-design of the MOOC as one of the future challenges of the University of Innovation in July. The group was divided into two teams: a) one sharing its own learning experiences in MOOCs to identify positive and negative users' experience and b) the other working with persona (portraits of potential learners from survey results) to define learner's needs. At the conclusion, the whole group prepared a timeline to organize the project between March and July.

During that period of time, the design team organized participatory and co-design workshops with potential users and learners. One co-design workshop was held in May, a second workshop was held in June, and a final presentation of results workshop in July in which the first prototype of the MOOC's architecture was presented.

After having presented the emergence of the design of the MOOC, we will now focus on two co-design workshops to present the means and methods used, and the artifacts produced.

3.2. The June Session: Co-Design of the MOOC Architecture

The June session was held using co-design methods to help prototype the macro-design of the MOOC. Public administration staff, Institution staff, and consultants were invited to join in a co-design day workshop held in the learning lab of the Institution.

The learning lab (Figure 3) was specifically designed and fitted to promote collaboration, being equipped with mobile furniture and technologies. Technologies supported collaboration (for instance using digital software such as virtual post-it for brainstorming) and gave access to inspiration sources (using the Internet to find sources or to communicate with others).

Figure 3

Mobile Furniture and Collaborative Technologies

During the entire session, participants worked together in teams to produce collective artifacts (Figure 4).

Figure 4

Team Work

Note. One of the teams is defining how to enable face-to face meetings for the participants in the MOOC and finding inspiration from using existing tools from the Internet.

The co-design method focused on producing artifacts in limited time using craft materials, technologies, and creative processes to prototype (Figure 5).

Figure 5

Prototyping Kit 1

Note. Prototyping kit 1 included stickers, labels, colored piece of rough paper, pen, glue, fixing paste, and more.

One of the critical phases of co-design is the testing. In participatory design, users participating in the design make the tests. In our case, the testing phase took place between the team members themselves and also with an external specialist working in Canada, using Skype (Figure 6). The testing phase relied on listening skills and benevolence, testers added ideas by completing those of others (Figure 7); the facilitator's posture and guidance were a key success factor to prevent debates and frustrations.

Figure 6

Testing Session With a Specialist in Canada Through Visio-Conference.
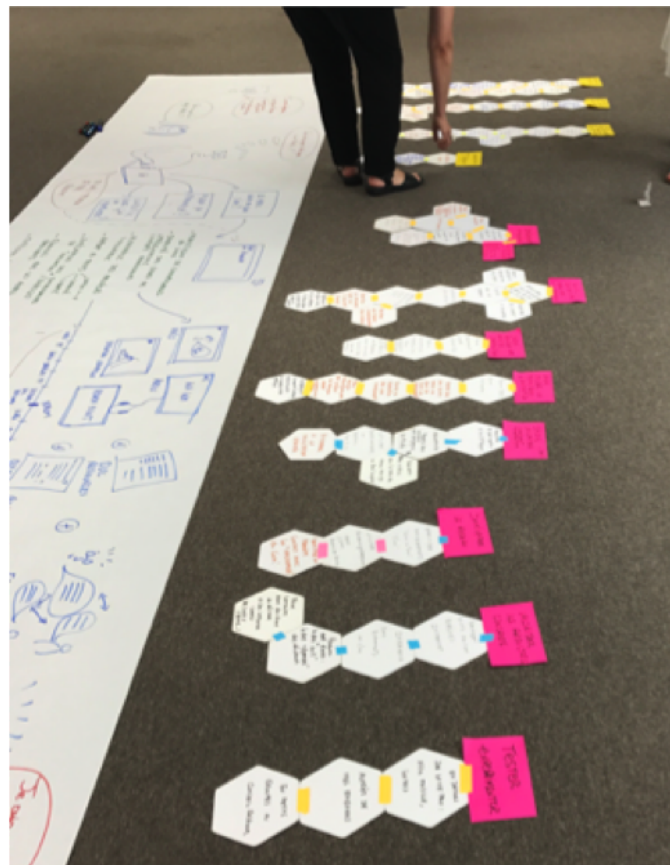
Figure 7

One Team is Testing and Completing Ideas of Another Team

The co-design session was organized to produce and test prototypes. During the afternoon, each team had to produce a final prototype: a storyboard of a teaser presenting the MOOC. One of the teams also imagined the screens the participant of the MOOC would see when they would log in (Figure 8).
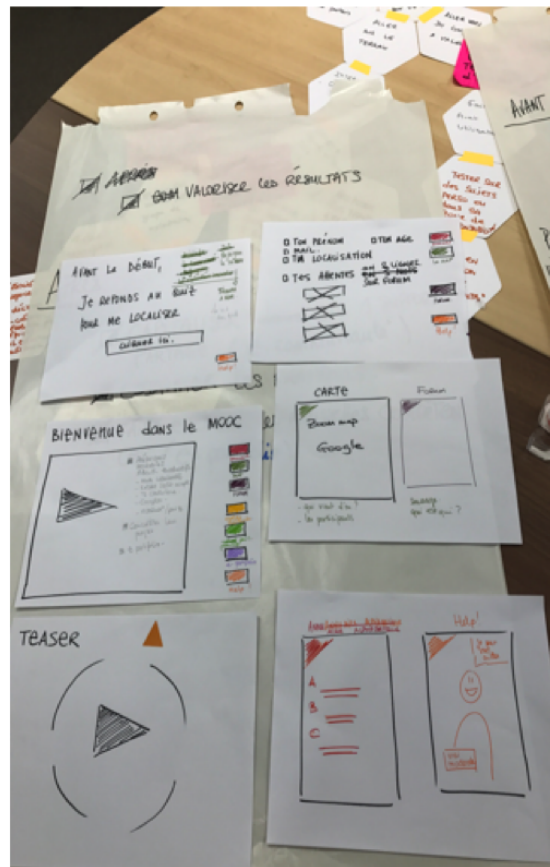
Figure 8

First Screens of the MOOC

The two other prototypes were teasers proposing a general theme to introduce innovation (with one of them using a cooking metaphor). The outcome of that day resulted from the participants' experience as users of MOOCs, the variety of participants, a facilitating environment, and collaborative design methods (rapid collaborative prototyping and testing). After this workshop, the design team used the prototypes to build a visual representation of the MOOC sequences timeline. It was to be tested during the July University's Public Innovation event.

3.3. The July Event: The University of Public Innovation

Civil servants looking to develop skills on public innovation attended the University of Innovation, alongside employees of the Institution itself, external consultants, and other guests (researchers, speakers, etc.). On the first day of the University, guests chose an innovation challenge and formed co-design teams; they worked together during two and a half days.

The group working on the MOOC consisted of 10 participants, half of whom were future users and the other half either employed or freelance designers. The group also included the Canadian specialist in Collective Intelligence Education and Facilitation, who participated in the June workshop. They tested the macro-design using the visual representation of MOOC sequences timeline made from the prototypes produced in June (Figure 9) and further co-designed the MOOC.
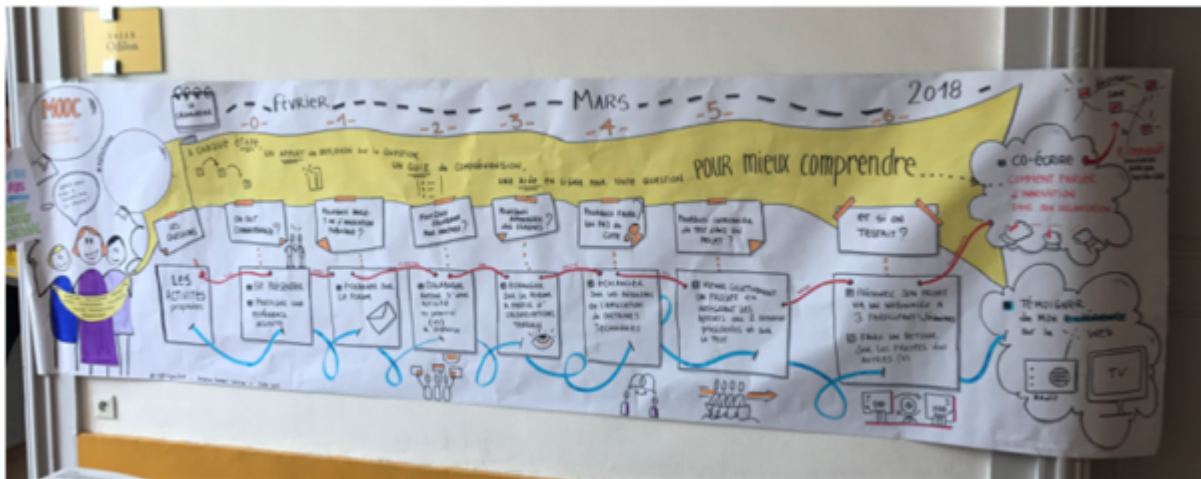
Figure 9

Visual Representation of MOOC Sequences Timeline Made From the Prototypes of June Sessions by a Graphic Designer

The co-design method consisted in producing collective ideas and artifacts in small teams (similarly to the June session). Each production was first presented to the other teams to benefit from their feedback; then the team moved on to the next step of the co-design process. This loop was repeated several times. At the end, new prototypes were built.

3.3.1. Intermediary Productions

During two and a half days, participants were guided towards building new or deeper knowledge on the challenges they faced. For example, participants brainstormed on the main issues they faced in a connectivist MOOC (Siemens, 2005): enabling collaboration/ teamwork and sharing content (Figure 10).
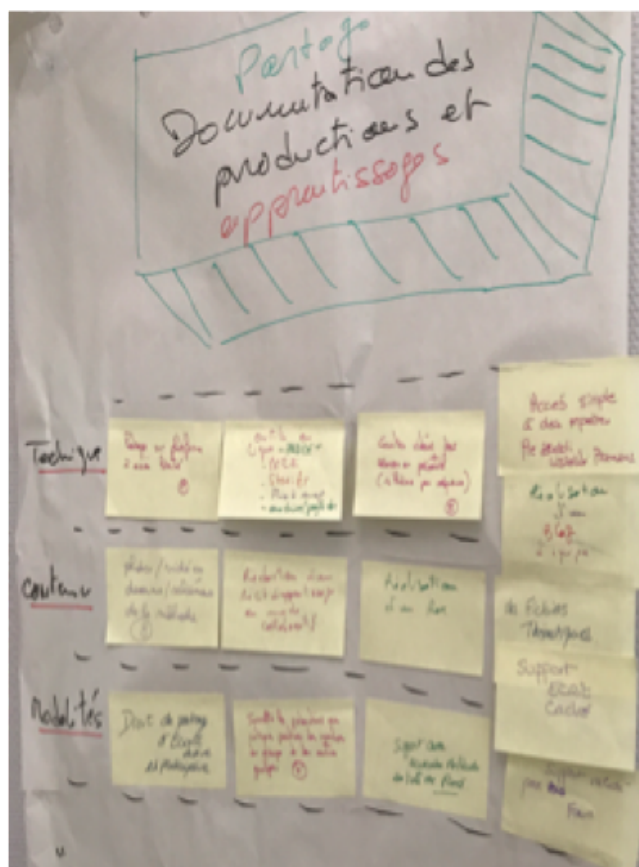
Figure 10

*Tools to Collaborate and Share Contents With Other Learners During the MOOC: "Techniques, Contenus et Modalités"
(Techniques, Content and Modalities)*

The MOOC features were discussed on a technical basis that both limited and inspired creativity. The participants challenged the project leaders' vision. They were worried that a cooperative model would be too time consuming and implied too much commitment for the learners, whereas the project leaders had the idea of building a co-learning MOOC (cf. *supra*).

Participants then chose what was relevant to prototype in order to move forward in the design of the MOOC and identify its functionalities. Two critical points were addressed: stakeholders of the MOOC on the one hand and expectations of users on the other hand.

3.3.2. Collaborative Prototyping

Two new prototypes were produced during this session: a description of the stakeholders as personas (Figure 11) and some functionality tests. Those tests featured learners' objectives and their role in the MOOC: either reading, contributing, or recruiting other participants.
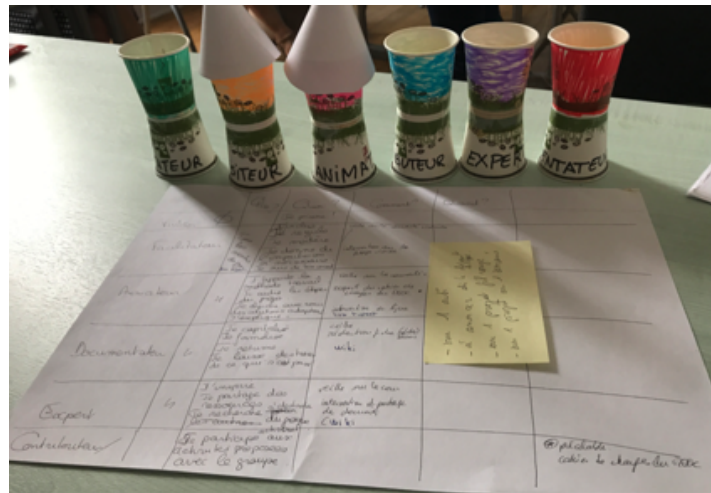
Figure 11

Persona: Facilitator, Visitor, Documenter, Expert, Contributor, Animator and Their Role in the MOOC

3.3.3. User Testing

The July co-design session ended with a final test conducted using all current attendees of the University. The team disrupted the pre-established program of the University of Innovation. Instead of just preparing an exhibition of the MOOC prototypes as initially planned, they asked visitors to take a stand on the features and objectives of the MOOC. Most of the testers chose the objective: "activate a process of collaborative innovation" (Figure 12 and Figure 13).

Figure 12

Testing the Prototype
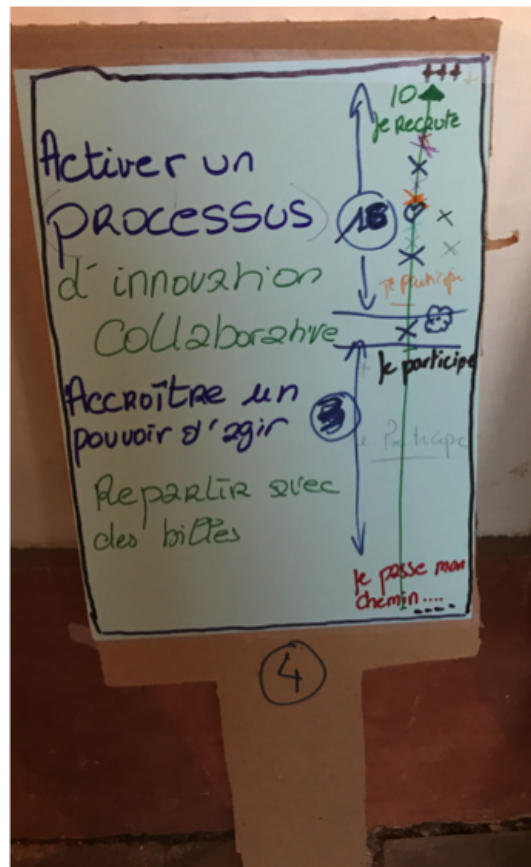
Figure 13

Positioning Oneself Among Three Objectives: "Activate a Process of Collaborative Innovation," "Increase One's Empowerment," and "Get Some Useful Tips."

After the University of Innovation, the design team of the MOOC further adjusted the final design while developing the pedagogical resources. They also organized a few more end-users testing just before implementing and opening the MOOC in May.

4. The Final Production Stage -- Reflections From a Professional Development Perspective

4.1. The MOOC Course Itself

We here describe the final product and design of the MOOC that were developed in June and July codesign sessions. The learning goals of the MOOC focused on public innovation. More specifically, after completion of the MOOC course, participants were be able to:

- Encourage and share local public innovation with people from various horizons,
- Experiment face-to-face or conduct remote collaborative work with peers and stakeholders,
- Advance projects using individual or collective innovation initiatives,
- Acquire the main benchmarks of an innovation approach and associated digital tools.

At the beginning of the MOOC, the course design offered participants to choose the discovery learning path or the collaborative learning path and organized themselves in project teams. The MOOC lasted 8 weeks, each week being a learning session (Session 1: Onboarding; Session 2: Territorial Public Innovation; Session 3: Collaborate, an innovative stance; Session 4: Innovate in context; Session 5: Learning from users; Session 6: Mobilizing Creativity; Session 7: Test

your project; Session 8: Presenting your project (Figure 14). The MOOC was hosted on the FUN platform (Figure 15). About 3800 people registered for the MOOC, and 7% received a completion certificate (Tcheng Blairon, in press).

Figure 14

Teaser Access, https://edtechbooks.org/-Emv
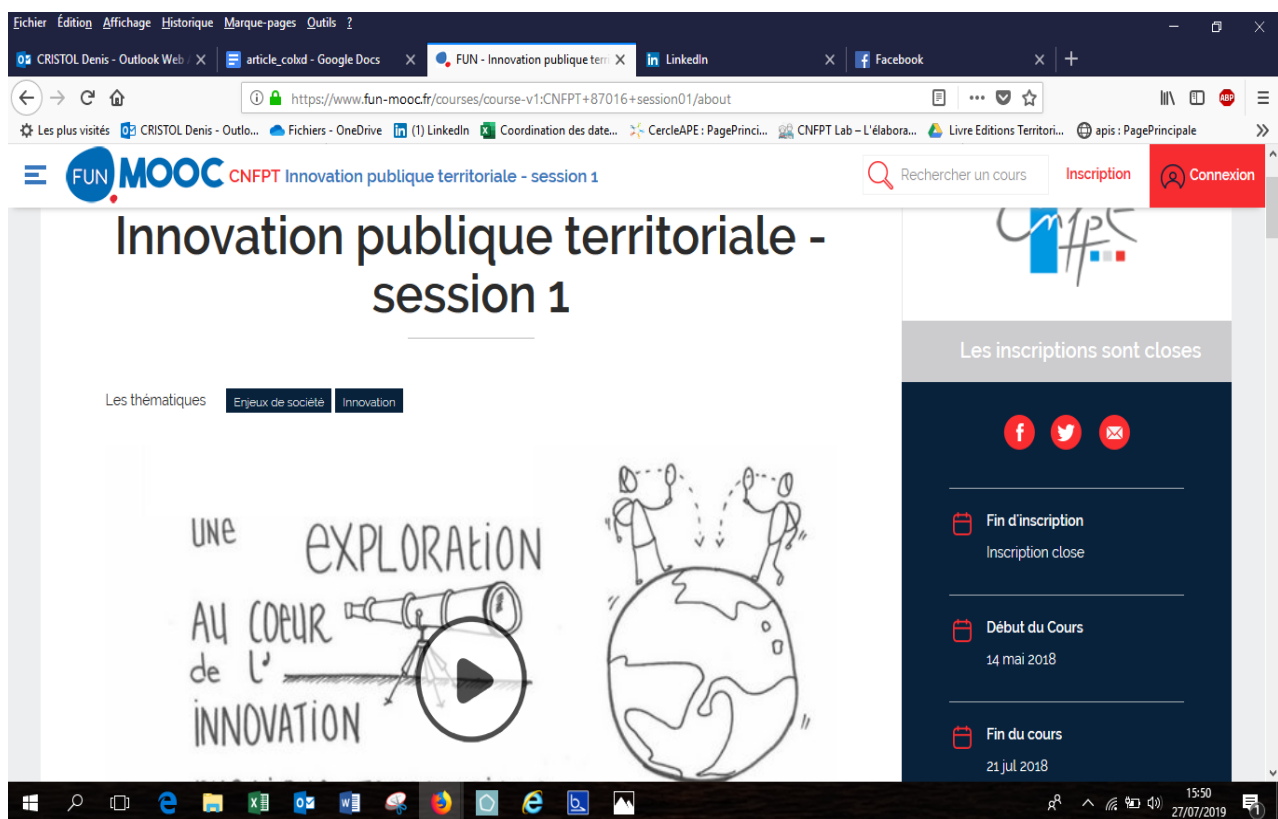
Figure 15

Une Exploration au Coeur de l'innovation/An Exploration at the Heart of Innovation

4.2. The Design Teams' Reflection on Learner Experience Design (LXD) From a Professional Development Perspective

Using a co-design and a participatory design process (Sanders & Stappers, 2008, 2014) enhanced the learner experience in three ways: a) by creating a pre-tested learning environment that used co-design and co-construction of the MOOC architecture, b) by committing that future learners who participated in the design would be influencers in the MOOC, and c) by changing the facilitators and designer's mindset through their involvement in the co-design sessions working with users as partners (cf. The University of Innovation).

The team design built the co-design session's program focusing on conditions of participations (Clement & Van den Besselar, in Kensing & Blomberg, 1998), following these concepts:

- Access to relevant information (inspirations sources, information on MOOCS, etc.),
- Possibility to have one's point of view (benevolent guidance),
- Participation in the decision (testing others productions and prototypes),
- Communicate the method (participatory design thinking method),
- Possibilities to alternative technical/organizational arrangement (no specific constraints during the macro-design and possibilities to adjust the features).

The enlarged design teams learned from one another through collaborative work and testing. End-users (learner and promoters of the MOOC, in our case), being part of the design, were able to express their need during the sessions and throughout the process. Project managers and designers adjusted their design to the learners who participated actively in the design. For this participatory-co-design method, we applied adapted facilitation methods and tools to favor oral communication, to develop listening skills, and to help stakeholders engage in the process. It included design materials and collaboration tools as well as a dedicated space to move and interact.

From our perspective, learner experience design (LXD) is not only based on the learning experience related to technology (ergonomic, design, etc.) or the learning process of the MOOC, but also implies a participation in the design process itself that can drive change. In our case, LXD resulted in the decision to create two training courses within the MOOC: a discovery MOOC and a cooperative /enhanced MOOC involving work on a team project. The team design initially planned to focus the design on a connectivist MOOC that allowed learners to build up their knowledge working on team projects.

5. Discussion

5.1. Has This Process Encountered Some Pitfalls, How They Were Overcome?

The co-design of this MOOC played a role in exploring new, hybrid end-users' learning practices and situations that contributed to the design team's change of pedagogical format.Some difficulties arose and dealing with them played a part in this change.

First, participatory design and co-design sessions need a sufficient number and variety of participants in order to share information and practices while building up collaboration. Both May and June sessions were planned as participatory design sessions. However, in May, only one external person joined the MOOC project team. The call for volunteers did not work for this session. The one person who joined the two designers did not have sufficient information to contribute. The designers spent most of their time explaining rather than testing their ideas with her. The project had therefore to be adjusted; it required the design team to be flexible enough and to adapt the June session's program.Second, regarding the method and means, some adjustments also had to be made. During the June session, one of the teams met some difficulties in prototyping a teaser and was not able to use the kit at their disposal. Finally, they were able to catch up and ended with a proposal. However, they expressed frustration, which had to be addressed by the facilitator. Participation of users who are not familiar with co-design can lead to tensions; the facilitator's role is therefore crucial to lead them into the process of experimenting. Experimenting and prototyping suppose an ability to accept making mistakes (test and learn) and using something new (prototyping kit). Third, changes regarding graphic and technical aspects lead to updating the final features of the MOOC, giving up the initially chosen supplier, and integrating collaborative and group-building activities into the FUN platform.

5.2. Implications

The findings of this case allow us to offer some implications and project design recommendations for researchers and practitioners when using co-design and a participatory process:

- It is important to have enough people to participate in the co-design sessions and a minimum of 8-9 people to organize more than two working teams.
- It is important to have a variety of backgrounds, domains, and experience knowledge. This knowledge can also be nourished through online resources.
- Participation need to be facilitated and regulated by a professional facilitator, to support social learning (Bandura, 1997)
- It is best to provide a variety of working means so everyone can contribute. Not everyone is comfortable with making visuals or writing things down on post-its (using the tool kit).
- Changing existing design processes in an organization can be hard. It's important for all participants to be open-minded and willing to try new things.
- Given the often-limited functionality of online learning platforms, it's important for participants to design with those constraints in mind so they don't develop ideas that are difficult or impossible to realize in the implementation phase such as highly collaborative activities.
- For those facilitating these workshops, time management is key. Allow for the unexpected to occur and build in more time for explanations than you think you need.

5.3. The Complexity of the Issues Related to the Design of a Blended or Hybrid MOOC

Creating a new training product with users generated various consequences, which could not be anticipated but led to more flexibility in the design of the MOOC. The complexity of the project consisted in managing a variety of issues and actors. Incorporating users in the design process led to longer delays, higher budgets, and different teaching practices than those commonly accepted. Actors and sponsors who did not participate in the design, but who had a decision power in the project (over technical resources, budget, communication, organization of face-to-face courses), asked for more details than usual.

Through the process, participants in the co-design became partners and actors in the participatory process and influencers during the MOOC implementation. The broadening involvement of participants demonstrates the conclusion of research showing the participatory design effect is noticeable far beyond the design itself (Hansen et al., 2019). Co-design has other benefits; research shows that users becoming partners in the co-design can improve the "self-sustain" of a MOOC (Kennedy & Laurillard, 2019).

6. Conclusion

The MOOC was expected to give the rudiments of knowledge on the topic of *public innovation* and to enrich the ecosystem of the French public service. The second season of the MOOC intended to promote the recruitment of participants and to give them elements of common language. As a result of the MOOC's influence, the numbers of participants in the University of Innovation rose from 170 people in the second edition of the University, to 1000 during the third edition. and to more than 2000 during the fourth.

The co-design practices have been delivered to several units within the Institution, the consultation of users made it possible to qualify e-learning activities (in terms of learner experience) and to enrich the practices of the training team of the Institution. Indeed, new techniques like forum controversies, face-to-face workshops, weekly webinars, and online workshops in collective intelligence were added to the panel of activities of designers and public officers in charge of developing MOOCs in the Institution.

Our case demonstrates that instructional/UX designers using participatory/co-design methods can powerfully achieve two goals: a) Enhancing the learning experience of end-users and b) contributing to the professional development of the design team involved in the project (e.g., project managers, training consultants, and instructional designers) (Cavignaux-Bros, 2018; Cavignaux-Bros & Cristol, 2018; Cristol & Cavignaux-Bros, 2019).

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Acknowledgements

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[1] 12 sessions individually lasted between half a day to three days. During the session data was collected by taking notes and pictures and focused on the human and material resources used and on productions.

[2] https://www.fun-mooc.fr

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Supporting Equity in Schools: Using Visual Learning Analytics to Understand Learners' Classroom Experiences

Ali Raza, William R. Penuel, Jennifer Jacobs, & Tamara Sumner

Design   Equity   Visual Analytics   Sense-making

This chapter discusses the affordances of applying user experience (UX) methods to designing technology for understanding learners' classroom experiences. The chapter highlights a student survey designed to support teachers in building equitable classrooms. The surveys, called "Student Electronic Exit Tickets," are based on three constructs related to equity: coherence, relevance, and contribution. Survey responses are provided to teachers through a visual analytics dashboard intended to help them readily interpret their learners' experiences. We explain how UX methods, such as think alouds and cognitive interviews, guided design choices in the dashboard that help teachers attend to equity concerns by disaggregating student data by gender and race. UX methods were also used to validate our argument that visual analytics can be a supportive agent for teachers, prompting them to notice and attend to inequity in their classes. We propose an agenda for future designers of educational technology that incorporates UX methods in the creation of tools that aim to make learning in classrooms more equitable.

1. User Experience Methods as a Vehicle for Producing Equitable Visual Analytics

Baker and Siemens (2014) argued that learning sciences as a field has been late in adopting analytics, compared to other disciplines such as biology which first published an analytics scientific journal in 1970. A variety of tools and methods have been employed in learning analytics (LA) for making predictions (e.g., classifiers, regressors, and latent knowledge estimators) and for structure discovery (e.g., clustering, factor analysis, social network analysis, and domain structure discovery). A reference model for learning analytics based on the following four dimensions—data and environments (what), stakeholders (who), objectives (why) and methods (how)—has been proposed, and the LA literature can be mapped onto this reference model (Chatti et al., 2013).

Researchers from the LA community emphasized the importance of human-centered design (HCD) methods being incorporated in the field of LA and laid out an agenda for human centered learning analytics (Buckingham Shum et al., 2019). Holstein and colleagues (2017) applied UX methods to the gathering and understanding of teachers' needs in ways that enable intelligent tutor dashboards to support them. First, the researchers conducted four types of design

interviews (generative card sorting exercises, semi-structured interviews, directed storytelling, and speed dating) with ten middle school teachers. These interviews provided guidance on prototyping an augmented reality glasses application for monitoring student performance in the intelligent tutoring system in real-time. They also provided insights into teachers' perceptions of what they consider to be useful analytics (e.g. analytics currently generated by the intelligent tutoring system were not considered to be actionable). Similarly, Ahn and colleagues (2019) provided insights on the value of using HCD methods (contextual design, design tensions) with teachers for designing analytics dashboards providing data on student learning and supporting the improvement of teaching practice. To understand teachers' perceptions related to visual analytics, they used methods including case study, participant observation, interviews, affinity mapping, and think-aloud. Dollinger and colleagues (2019) stressed the importance of involving stakeholders in the creation and design process of learning analytics tools. They conducted a case study on using and developing LA in several Australian universities spanning over six years. Some of the advantages resulting from this co-creation process were (a) ongoing usage of the platform, (b) expanding the user base, and (c) incorporating modifications and additions from user feedback and suggestions.

Typically, teachers are provided with access to learning analytics through instructor dashboards, i.e., user interfaces that present automated analyses of student data, including visualizations and opportunities to "drill down" more closely examine the underlying data. For instance, in a programming course, instructor dashboards providing real-time data analytics have been implemented to make predictions about the state of a learner based on their grade assignment by the teacher (Diana et al., 2017). Supervised machine learning algorithms along with human graded scores were able to successfully predict the learners' task state, enabling teachers to identify struggling learners. In another example from mathematics education, automated analysis of classroom video data has been used to provide feedback to teachers about the nature of their classroom discourse through an analytics tool called TalkMoves (Suresh et al., 2018). The TalkMoves tool uses deep learning models to detect well-defined discussion strategies called "talk moves" (Michaels et al., 2010) and generates visualizations that allow teachers to gain new insights into their instructional practices.

The various emotional states of learners during a video-based instructional session on foreign language development can be identified by analyzing audio, video, self-reporting and interaction traces (Ez-Zaouia & Lavoué, 2017). Based on this research, a teacher-facing dashboard called EMODA was created that informs instructors about learners' emotions during lessons so that they can quickly adapt their instructional strategies. Different visualizations are provided in the teacher dashboards that provide access to the learners' emotions and prompt an alteration of instruction as appropriate. Hubbard et al. (2017) generated a novel intervention that measures learning with the use of virtual reality and EEG headsets. The intervention works by creating a closed-loop system between the virtual and EEG biological data to generate information about the user's state of the mind. Researchers have also studied other physiological measures (such as heart rate and facial expressions) and their relationship to learning (Di Mitri et al., 2017; Spaan et al., 2017; Xu & Woodruff, 2017). In summary, the field has started exploring and adopting human-centered or user experience design methods for a better adaptation of the learning analytics systems to support data-driven instruction. There is also a push to understand the relationship between a number of physiological and contextual measures centered around learning and teaching. Given the abundance of learner experience data that can potentially be made available, research involving UX or HCD methods should involve the different stakeholders that use data to make teaching and learning more equitable in classroom settings.

2. Understanding the Use of Data-Driven Decision Making in Schools

Using data to bring about change in instructional practice or to make more informed curricular decisions is not a new endeavor in most schools. The enactment of No Child Left Behind Act (2001) and the American Recovery and Reinvestment Act (2009) increased pressure on schools to be accountable for their actions based on concrete data (Kennedy, 2011). Schools and classrooms can offer rich bodies of information on learning experiences, but developing and applying suitable technology for generating usable knowledge has been a challenge (Wayman et al., 2004). Effective software must be designed to scaffold the analytic process of interpreting learners' data. Readily interpretable

learner experience data can promote increased use of this type of assessment practice by teachers and motivate efforts to promote epistemic justice in the classroom (Penuel & Yarnall, 2005).

2.1. How Data-Driven Decision Making Supports Teachers and Schools

Researchers recommend involving teachers in data driven decision making in order to become more knowledgeable about and attentive to the individual needs of their students (Schifter et al., 2014; Wayman, 2005). Wayman and Stringfield (2006) highlighted three avenues to support teachers' use of data systems: professional development, leadership for a supportive data climate, and opportunities for data collaboration. Mandinach and colleagues (2006) proposed an interesting approach to decrease the mismanagement of data as it moves from the district to individual schools. They defined a conceptual framework for managing data and generating informed data driven decisions based on six cognitive skills: collect, organize, analyze, summarize, synthesize, and prioritize. Data stakeholders such as teachers, principals and district leaders systematically work their way through these skills in order to mine, make sense of, and generate recommendations from the data. Ysseldyke and McLeod (2007) emphasized the importance of using technology to monitor the responses of students as part of a continuous feedback loop. They note that a variety of data tools (such as Plato Learning, McGraw-Hill Digital Learning, and Pearson Prosper) provide in-depth information to teachers, principals and school psychologists that might lead to improved instruction.

Wayman and Stringfield (2006) stressed the importance of including the entire school faculty in the use of student data to improve instruction. The researchers conducted a study in three schools where they involved all faculty members in the process of utilizing student data and observed changes such as increased teacher efficiency, better response to students' needs, support in analyzing current teaching practices, and an increase in collaboration. Van Geel and colleagues (2016) carried out an intervention based on data-driven decision making in 53 primary schools to explore the impact on students' mathematics achievement. Based on two years of longitudinal data, they reported an increase in student achievement, particularly within lower socioeconomic status schools. Staman and colleagues (2014) created a professional development course designed to help teachers learn to carry out data-driven decision making activities. The course included a data-driven decision making cycle that consisted of four phases: evaluation of results through performance feedback, diagnosing the cause of underperformance, process monitoring, and designing and executing a plan for action. Results from their study indicated that the professional development course had a significant and positive impact on the school staff's skills and knowledge.

Schildkamp and colleagues (2012) investigated a discrepancy between data from local school-based assessments and national assessments and found that the largest discrepancies were related to students' gender and ethnicity. This study raises questions about the data analysis capabilities of the instructors who were not able to figure out why these discrepancies arose or take any subsequent action. Schildkamp and Kuiper (2010) argued that to continuously improve schools' capacity to provide better instruction to students, teachers need to become capable of engaging in data analysis. To that end, training should be provided to teachers and school leaders, and collaborative data analysis teams should be established that include all stakeholders.

To promote more inclusive instruction, Roy and colleagues (2013) developed a differentiated instruction scale that focuses on serving the needs of all types of learners in the classroom. By considering data generated from this scale, teachers can test the effectiveness of different instructional styles and monitor the academic progress of their students. In another study focused on school principals, Roegman and colleagues (2018) documented their thinking about accountability and the use of data to inform instruction. The researchers found that principals mainly considered data exploration and analysis as a tool to help schools and students do well on standardized assessments, and their primary interest was in various types of student assessment data. The researchers argued that preparation programs can play an effective role in helping principals to consider and utilize data in a more varied and enriched manner.

2.1.1. Emerging Trends Related to Teachers' Involvement in Data Practices

This literature review highlights several emerging trends on how to engage teachers in data practices so they can improve their instruction and focus on understanding and meeting the needs of all students:

- Teachers need professional development on how to conduct data analyses and to ensure the collected data is meaningful for motivating improvement in the classroom.
- Teachers in the same school should be supported to collaborate and share data, provide support and guidance to each other as they try out new pedagogical practices in their classrooms, and understand and accommodate individual differences in student learning.
- Involving the entire faculty can help with analyzing significant amounts of data and designing new strategies to improve the process.
- Well-designed technology can play a positive role in helping teachers to understand instructions trends and patterns over time.
- Principals need support to become more knowledgeable about the different types of student data, and the broader range of uses beyond accountability.

2.3. Supporting Student Involvement in Data Sharing Practices

There is a growing emphasis in the research literature on the benefits of sharing student data with students themselves in order to create a shared understanding of the classroom experience and to collaboratively set learning goals based on those experiences (Hamilton et al., 2009; Kennedy & Datnow, 2011). Research has examined the impact and effectiveness of such data sharing, particularly with respect to its impact on student motivation. Marsh and colleagues (2016) conducted a study with six low performing high schools and found that engaging students with data can lead to a "mastery orientation" which increases student motivation, in contrast with a "performance orientation" that can be demotivating for most students. This study also highlights how a school, district structure, and leadership activities involved in promoting (or deemphasizing) data practices can affect students' motivation and interest.

Jimerson and colleagues (2016) focused on the effects of including students in making use of data and setting learning goals for themselves, which they termed "students involved data use" (SIDU). In this qualitative study with 11 teachers in 5 school districts, the results were mixed from the teachers' perspective. Some teachers believed that their students benefited from the SIDU approach, but there were some challenges, including managing time effectively, establishing a uniform vocabulary, and motivating the students. The authors suggested that additional research is needed to explore how teachers can introduce, implement and sustain this practice in an effective way. In another study, Jimerson and colleagues (2019) found that teachers perceived incorporating students in the analysis process as valuable, particularly as a way to improve their classroom practice by adjusting their instruction based on individual student needs. The teachers also felt that this practice was empowering their students and helped them to "own" their data. The authors concluded that involving students in data use can positively contribute to career-long improvement cycles for teachers, but it can also have unintended negative consequences that may affect students' attitudes and motivation and may infringe on students' privacy.

Apart from taking part in data practices, some high school students have been involved in shaping social justice policies, demonstrating that students can play an important role in school improvement (Welton et al., 2017). Researchers have emphasized the benefits of incorporating student voices in school decision making and policy implementation (Levin, 2000). By including students as agents of change, meaningful guidelines for their engagement can be elaborated, such as allowing students to participate in formal management processes, offering students training and support, and encouraging students to take part in discussions about proposed and resulting changes.

3. Student Electronic Exit Tickets (SEET): A Visual Analytics Tool Supporting Equitable Instruction at the Classroom Level

Understanding learner experience through a variety of quantifying methods can help in promoting equitable instruction for diverse classrooms (Penuel & Watkins, 2019; Rousseau & Tate, 2003; Shah & Lewis, 2019; Valiandes, 2015). Taking a student-centered approach and gathering reliable information about learners' experiences in the classroom can shed light on the learning community and processes from the students' perspective (Horan et al., 2010; Paris & Alim, 2017; Penuel & Watkins, 2019; Steinberg et al., 1996; Tinto, 1997). In a self-report survey, students identified the knowledge

gained from their peers while sharing out ideas during lessons as the most important aspect of their learning process, noting such peer-peer interactions makes the content more personal to them (Holley & Steiner, 2005).

Designing assessments that address issues related to equity and epistemic justice in the classroom is critical to understand learners' experiences (Penuel & Watkins, 2019). Collecting and engaging with these data can guide teachers to better align their instruction and curricular materials with learners' interests and experiences (González et al., 2001) particularly when it is evident that experiences differ depending on the student, task, and teachers (Penuel et al., 2016). Data designed to uncover students' perceptions direct attention towards noticing and understanding situations in which learners' experiences differ based on their race and gender and, in turn, how these differences impact overall classroom culture (Langer-Osuna & Nasir, 2016).

We argue that supporting equity involves understanding learners' experiences based on three constructs: coherence, relevance, and contribution (Penuel et al., 2018). To this end, we have created an assessment premised on these constructs called the Student Electronic Exit Ticket (SEET). SEET data provide targeted information about learners' experiences within a particular academic unit and classroom. Each construct comprises a unique set of questions. SEET questions related to coherence ask students whether they understand how current classroom activities contribute to the purpose of the larger investigations in which they are engaged. Coherent learning experiences appear connected from the students' perspective, where the progression of learning experiences is driven by student questions, ideas, and investigations (Reiser et al., 2017). Questions related to relevance ask students to consider the degree to which lessons matter to the students themselves, to the class, and to the larger community (Penuel et al., 2018). For contribution, SEET questions ask students whether they shared their ideas in a group discussion, heard ideas shared by others, and whether others' ideas impacted their thinking. The aim of using the SEET assessment in the classroom is not to judge teachers or identify students' understanding of disciplinary content. Rather, as shown in Figure 1, the assessment is intended to help create an environment for improving teacher instruction and diminishing classroom inequity. Gathering and studying data based on students' perceptions of coherence, relevance, and contribution can prompt teachers to minimize inequality and promote student agency.
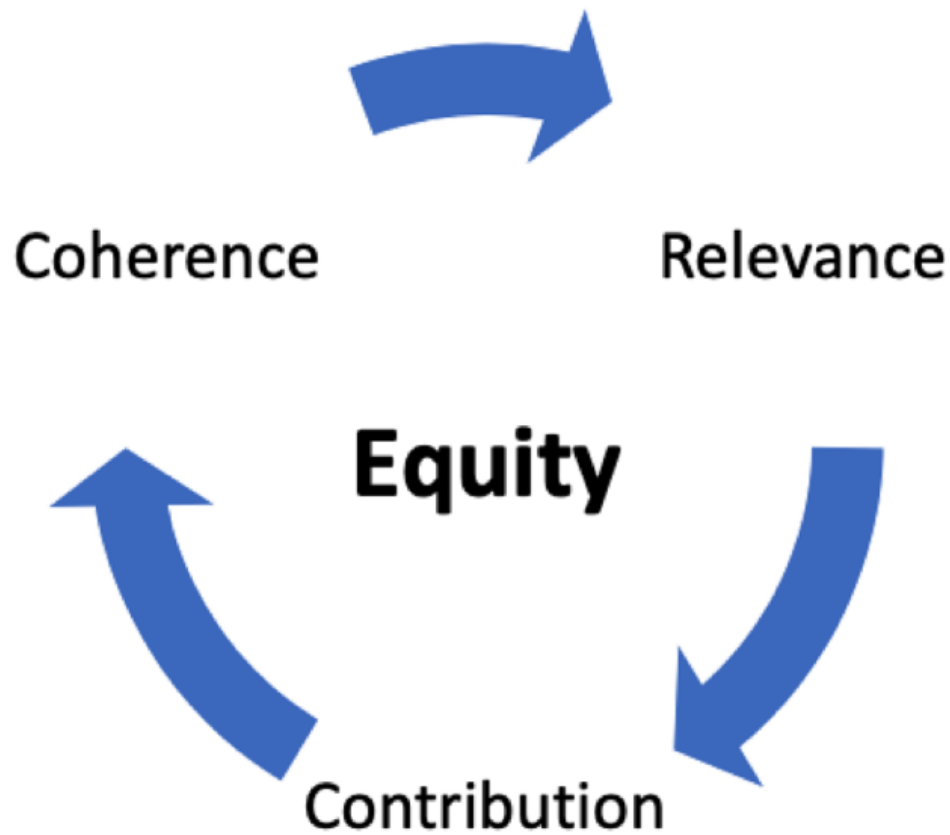
Figure 1

Framework for Supporting Equity in Classrooms Using Three Constructs: Coherence, Relevance, and Contribution

In this section, we describe the design of the SEETs as a visual analytics tool. Teachers first gather student data using SEETs toward the end of a lesson or curricular unit. They then view patterns within and across their classrooms, looking at student data disaggregated by gender and race. Teachers can also visually track their students' experience over time and examine the degree to which changes occurred.

The conjecture map in Figure 2 illustrates our ideas about how visual analytics tools can support more equitable classrooms. In design-based research, a conjecture map is used as "a means of specifying theoretically salient features of a learning environment design and mapping out how they are predicted to work together to produce desired outcomes" (Sandoval, 2014, p.19). By designing tools to meaningfully display student experience data, we conjecture that teachers can adjust their instructional decisions and actions to create an equitable environment.
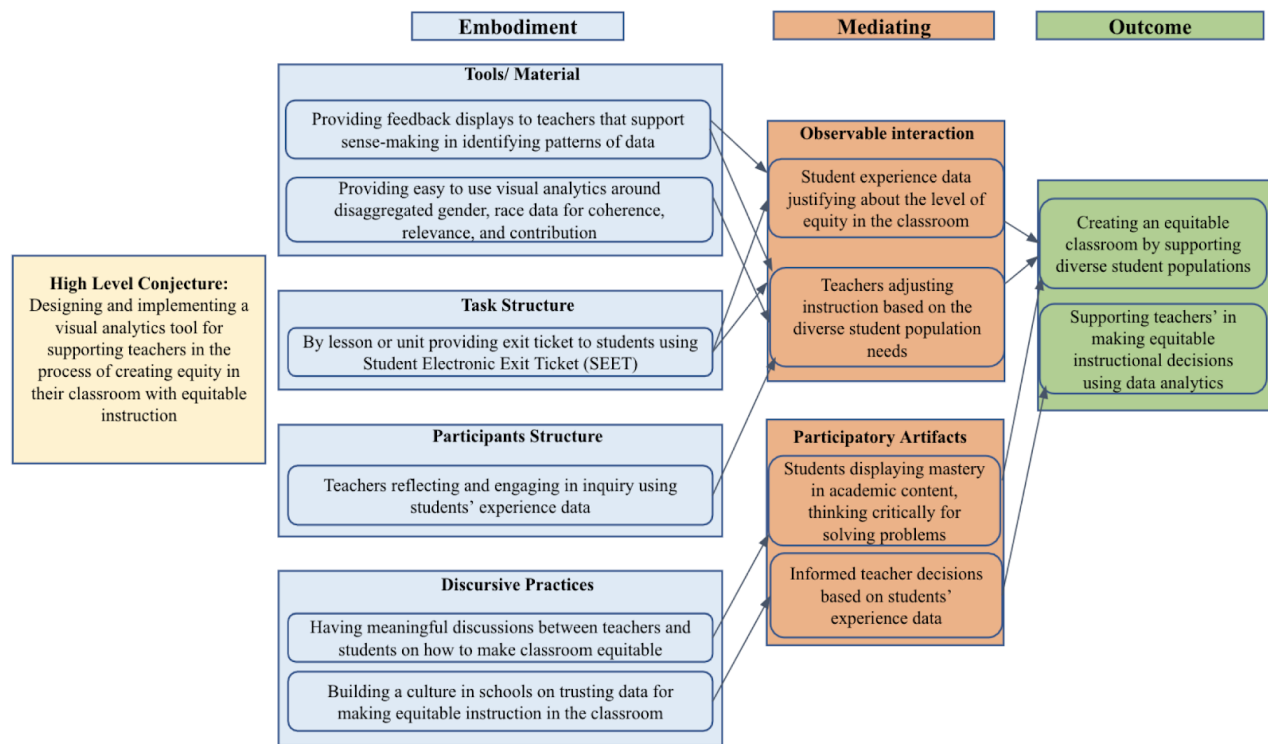
Figure 2

Conjecture Map for Designing the System and Achieving Desired Outcomes

We present two use cases to illustrate how applying user experience methods impacted the tool's design and development process to meet our objective of promoting equity from the lens of teachers. A use case is a methodology used by software development teams to guide their processes. The methodology involves determining the central requirements that will lead to the proposed solution or software components, drawing on advice and feedback from stakeholders or other relevant actors (Cockburn, 2000; Jacobson, 1993). Based on a research practice partnership between the University of Colorado Boulder and a large urban school district in Denver, Colorado, we describe two use cases that utilize different user experience methods in an effort to gather feedback on the design of the visual analytics tool addressing equity.

3.1. Use case 1: Using the think-aloud method

The think-aloud method is a way of understanding the cognitive processes of the participants when a stimulus is introduced during decision making (Kuusela & Pallab, 2000). The central goal of this method is to gather participants' verbal reasoning as they search for information, evaluate their options, and make the best choice. We selected this user experience method for gathering feedback on the visual displays of the SEET data by focusing on the sense-making of the teachers. Our research team drafted thirty possible data visualizations based on representative student experience data in order to determine which visualizations were most useful to middle school teachers. We used these visualizations as a stimulus for gathering information related to the design of the dashboard. We also attended to the teachers' data and visual literacy skills as they sought to make sense of the visualizations. With the growing emphasis on using data for decision making in schools and for improving instruction (Marsh et al., 2006; Marsh et al., 2016; Stecker et al., 2008), analytics tools need to be designed so that they match teachers' data and visual literacy skills and are not subject to biased or ambiguous interpretations (Szafir, 2018).

All teachers who were included in the design process taught science at the middle school level and used a problem-based approach to teaching. Think aloud and cognitive interviews were conducted simultaneously in two iterations (iteration 1: five science teachers; iteration 2: two science teachers) with seven randomly selected teachers (four males, three females). In our think-aloud studies, we showed the teachers different visualizations based on analytics from

sample classroom data addressing students' perceptions of coherence, relevance, and contribution. Teachers were asked to verbalize their thoughts as they sought to interpret these visualizations and answer questions posed by the research team about the data.

During iteration 1, the first three teachers selected two visualizations (horizontal stacked bar and connected scatterplot) that they felt best supported them in making sense of the data. Based on the feedback of the last two teachers in iteration 1, we switched to different visualizations; those two teachers nominated the following visualizations as the most useful: heat map, bubble chart, and line chart. In iteration 2, with two new science teachers, we included the preferred visualizations from the first iteration along with some new visualizations for the teachers to consider. The two teachers selected three visualizations as the most conducive to sense-making: horizontal bar chart, heatmap, and connected scatterplot. Based on teachers' suggestions, along with our observations of teachers' visual and data literacy skills, we selected a horizontal bar chart, a heat map, and a connected scatterplot as the most appropriate visualizations of disaggregated learner experience data (see Figure 3). Most of the teachers indicated that these data displays were consistent with their abilities and expectations in interpreting data and provided them with an easy and unbiased understanding of the learners' experiences.

Connected scatterplot displaying overtime learner classroom experience

Bar chart disaggregating learner experience data by gender and race
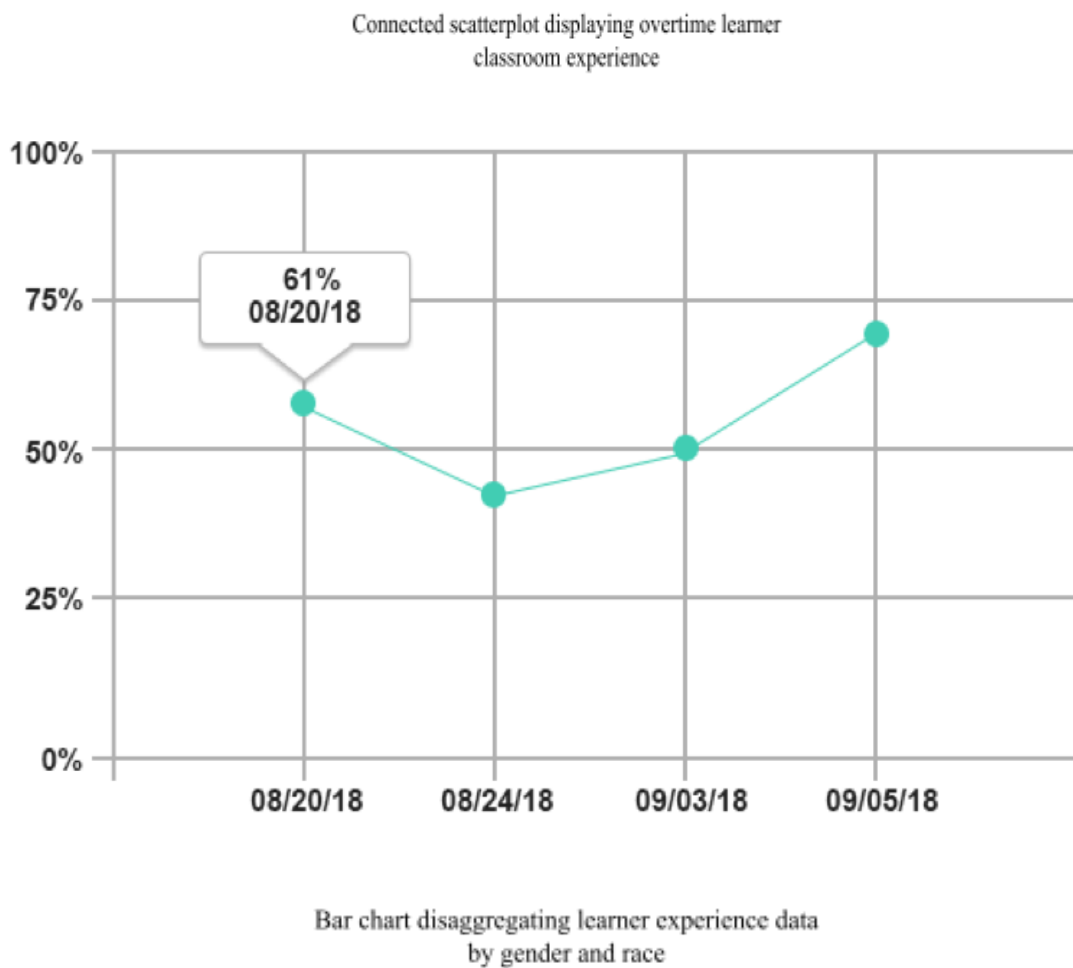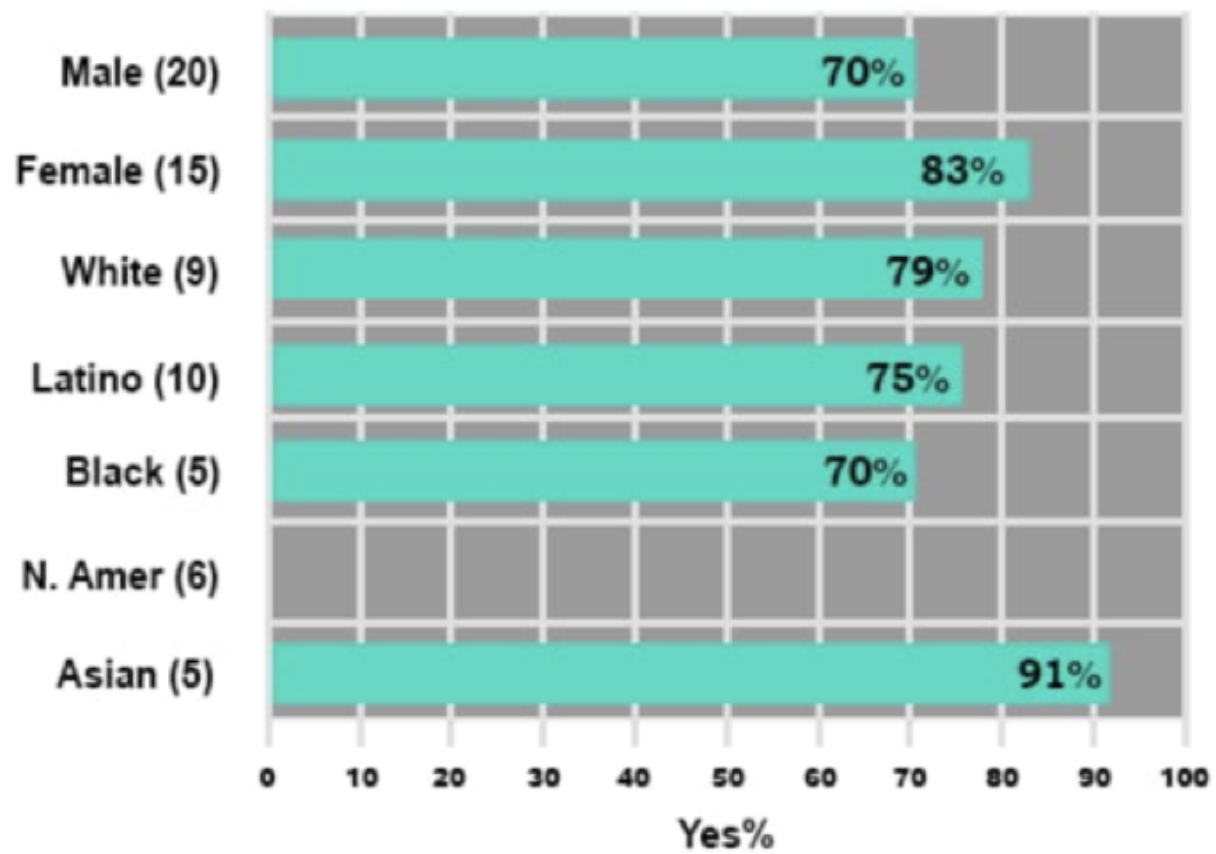
Heatmap disaggregating learner experience data
by gender and race

Male	60	70	80	90	50	60	80	90	60
Female	40	80	40	70	40	50	70	70	80

White	60	80	40	90	50	60	80	90	90
Latino	40	80	60	70	40	50	70	70	80
Black	50	60	40	80	60	40	90	70	60
N. Amer	50	40	40	60	60	40	70	80	60
Asian	50	60	50	40	60	60	80	60	60

Figure 3

Selected Visualizations From Teachers Providing Feedback of Learner Experience

Teachers also provided design recommendations to make the visualizations more readily interpretable and to support a comparison of results within and across constructs. An example of such a recommendation is shown in Figure 4. In this case, teachers suggested using the same background color for questions belonging to a similar construct, to make it easier to view patterns within that construct.

Coherence : Today we used the Driving Question Board to remind ourselves of what questions we had that we've answered in previous classes

	Yes%
Male (20)	70%
Female (15)	83%
White (9)	79%
Latino (10)	75%
Black (5)	70%
N. Amer (6)	—
Asian (5)	91%
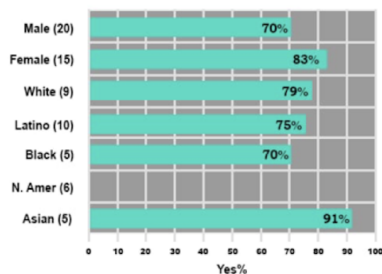
Relevance : What we did in class today matters to people in my city or town because:

	Yes%
Male (20)	44%
Female (15)	72%
White (9)	68%
Latino (10)	32%
Black (5)	33%
N. Amer (6)	17%
Asian (5)	40%
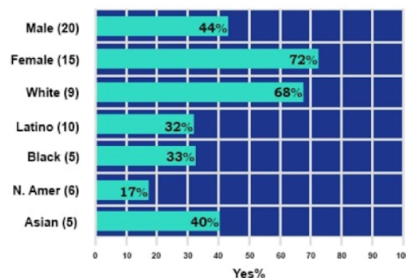
Contribution : Did any other students share ideas out loud today to the whole class, a small group, or a partner?

	Yes%
Male (20)	75%
Female (15)	80%
White (9)	70%
Latino (10)	42%
Black (5)	39%
N. Amer (6)	31%
Asian (5)	50%
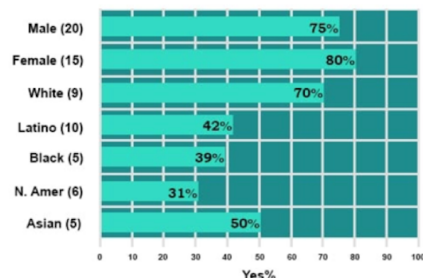
Figure 4

Design Recommendation for Highlighting Questions From Same Construct

3.2. Use case 2: Using Cognitive Interview

After the think-aloud, teachers then participated in cognitive interviews (Fisher & Geiselman, 1992). Cognitive interviews allow for an in-depth analysis of the validity of verbal reports of the respondents' thought process (Blair & Presser, 1993;

Conrad & Blair, 1996). Our interviews focused on the target constructs and how visualizations can reveal equity concerns in classrooms. Using this UX method enabled us to gather justifications for the selection of particular visual displays and also provided an initial understanding of how teachers attend to equity using visual analytics. We adopted the grounded theory approach for the analysis of the verbal scripts from think aloud and cognitive interviews (Charmaz, 2014). A recurring pattern that emerged during the cognitive interviews was related to teachers' thinking about how visualizations can promote new understandings and discussions around equity or inequity. There is general agreement that equity or inequity in the classroom can be created through the prevailing classroom discursive practices (Herbel-Eisenmann, 2011; Moschkovich, 2012). During the cognitive interviews, many teachers ideated on having discussions with their students based on the visualizations to further support equity and enhance the learners' classroom experience. As Joan[1] reflected during her interview when asked how these visualizations would help her understand the needs in her classroom:

> I think it would definitely give me some empathy. Especially here, in coherence for females. I would definitely drive my instruction to help target this group. Clearly if this was my class with my data, I did not do my job enriching these female students. So, that would really cause me to go back and reflect and hopefully make some changes. This piece of data would allow me to just directly ask them: What did you need that I didn't give you? (Cognitive interview with Joan, November 2018)

Cognitive interviews helped us, as designers of the SEETs, validate our view of visual analytics as having the potential to serve as a scaffolding agent for teachers to consider inequity in their classrooms. For example in her interview, Maggie described what she took away from the bar chart visualization:

> The instructional need would probably be making this culturally relevant to all students in the classroom, making sure that all students do find a connection to it, whatever they're learning. Because it's clear that all students aren't finding that connection from the lesson to what's important to them or their community, only some students are, and it's solely dependent on cultural background or ethnicity. (Cognitive interview with Maggie, December 2018)

The cognitive interviews enabled our research team to gather evidence on how cognizant teachers are about fostering equity in their classrooms. As part of our research practice partnership, the participating teachers were expected to play a significant role in the design and development process of various curricular and instructional products and to weigh in on the validity of assumptions made by the researchers. In this case, the teachers played a significant role in helping the research team to understand how the visualizations will be used, and improving the interpretability of the visualizations.

4. Conclusion

Learning experience design is an interdisciplinary and evolving field (Ahn, 2019). Prior research has identified many of the benefits and challenges of user-centered design when creating new technology (Abras et al., 2004; Greenberg & Buxton, 2008; Norman, 2005). Research within the learning sciences has a rich history of building on these ideals to promote learner-centered design (Soloway et al., 1994), including teachers and learners in the design process of systems meant to impact teaching and learning can provide an in-depth understanding of their expectations and help to identify motivations and barriers to adoption and use. This chapter illustrated how user experience design methods can be applied to the design of learning analytics systems where designers must grapple with multiple interwoven concerns, such as what data should be collected, how can it be displayed to support appropriate interpretations, and how visualizations can be crafted to promote useful feedback and instructional change. Ultimately, our goal is to create systems that support educators to thoughtfully reflect on their classroom culture, by providing useful data on their students' felt experiences and highlighting the critical role teachers play in shaping equitable classroom learning experiences.

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Acknowledgements

We would like to thank all the participating teachers in the work. Also, we would like to acknowledge the role of reviewers in shaping this work. This material is based upon work supported by the Spencer Foundation.

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15

Think-Aloud Observations to Improve Online Course Design: A Case Example and "How-to" Guide

Andrea Gregg, Ronda Reid, Tugce Aldemir, Jennifer Gray, Margaret Frederick, & Amy Garbrick

Instructional Design   User Experience   Learner Experience   Think-aloud Observations (TAOs)   Design Principles

User-experience (UX) problems in course design can be challenging for students as the web interface mediates most online learning. Yet, UX is often underemphasized in e-learning, and instructional designers rarely receive training on UX methods. In this chapter, the authors first establish the importance of UX in the contexts of both learner experience and pedagogical usability. Next the authors describe their study using think-aloud observations (TAOs) with 19 participants. This TAO study resulted in the identification of the following design principles for maximizing the UX of online courses offered within an LMS: (a) avoid naming ambiguities, (b) minimize multiple interfaces, (c) design within the conventions of the LMS, (d) group related information together, and (e) consider consistent design standards throughout the University. Finally, in this chapter the authors offer specific guidelines and directions to enable others to conduct similar TAO testing within their university context.

1. Introduction

User-experience (UX) research puts the emphasis on the perspectives of users: what they value, what they need, and how they actually work (U.S. Department of Health & Human Services, 2016). This emphasis is important as misalignment between designer intention and actual user experience can result in unintended consequences (Nielsen, 2012). Figure 1 illustrates a commonplace example of this misalignment when a number of users do not follow the designer's intended path.

Figure 1

Desire Path

Note. Photograph by Wetwebwork, 2008. Creative Commons license on Flickr.com.

UX testing provides a crucial bridge between designer intentions and user interaction. UX testing ultimately "reminds you that not everyone thinks the way you do, knows what you know, and uses the Web the way you do" (Krug, 2014, p. 114). Given that the web interface mediates nearly all experiences for online learners in their courses, online learning seems to be a natural, if not critical, area for UX research (Crowther et al., 2004). Indeed, as Koohang and Paliszkiewicz (2015) argued, "The sound instruction that is delivered via the e-learning courseware cannot alone guarantee the ultimate learning. It is the usability properties of the e-learning system that pair with the sound instruction to create, enhance, and secure learning in e-learning environments" (p. 60). UX in e-learning contexts matters and can impact learning—the time that learners expend on non-intuitive course navigation is time taken away from more important learning activities (Ardito et al., 2006; Nokelainen, 2006). Intuitive design is defined as design when "users can focus on a task at hand without stopping, even for a second" (Laja, 2019, para. 2) and design that does not require training (Butko & Molin, 2012).

While the merits of UX testing in online learning have been recognized, such efforts have typically lagged behind other fields (de Pinho et al., 2015; Fisher & Wright, 2010; Nokelainen, 2006). This relative lack of emphasis on UX in e-learning may be in part due to some educators' aversion to the conflation of "learners" with "users" (or "customers") that a UX perspective can suggest (e.g., Rapanta & Cantoni, 2014). Another potential explanation for the lack of focus is that, while some instructional design models emphasize evaluation of the design (e.g., Reigeluth, 1983; Smith & Ragan, 2005), very little of the feedback designers receive about online courses is specifically focused on UX (Rapanta & Cantoni, 2014). Therefore, even if designers are interested in UX methods to improve online course design, they may not know where to begin or how to proceed.

This chapter is intended to demonstrate how UX testing, specifically the think-aloud observation (TAO) method, can be used in instructional design and online learning contexts to improve course-design usability; the chapter is organized as follows. First, the importance of UX and online course usability is situated within the contexts of learner experience and pedagogical usability. Second, a TAO study conducted with 19 participants to identify areas of navigational ease as well as challenges is described including methods and findings. Third, specific steps and guidelines based on both the literature and the authors' reflective experiences are offered to enable others in instructional design contexts to conduct similar UX testing.

2. UX, Learner Experience, and Pedagogical Usability

Prioritizing UX in online course design assumes a learner experience paradigm, which at its core emphasizes the role and importance of the cognitive and affective experiences of learners (Dewey, 1938; Parrish et al., 2011). Dewey described learning as a transaction between internal and external factors or an individual and the environment:

An experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment . . . The environment, in other words, is whatever conditions interact with personal needs, desires, purposes, and capacities to create the experience which is had. (1938, pp. 43–44)

Dewey's conceptualization, while put forth well before Internet-enabled technologies, still applies to today's context. For online learning, the learner's experience is part of a transaction that takes place between the learner and the learning environment, which is largely mediated by the learning management system (LMS) interface from which the learners access their online course. Within this context, educators and designers are responsible for creating "environing conditions" that maximize learning (Dewey, 1938, p. 44). Improving these conditions necessarily requires an understanding of how they impact the learner. UX testing is a way to learn how the LMS interface—a primary "environing condition" in online learning—is experienced by learners in terms of intuitiveness, functionality, and even aesthetics. When considering online learning within this context, some of the learner experiences are inseparable from their experiences as users in the course interface.

A concept related to but importantly distinct from both learner experience and UX is that of pedagogical usability, which refers to a category of usability strategies meant to operationalize learning-centered design principles in online learning environments (Silius et al., 2003, p. 3). Pedagogical usability is defined as "whether the tools, content, interface and tasks of web-based environments meet the learning needs of different learners in various learning contexts according to particular pedagogical goals" (de Pinho et al., 2015, Section II, "Pedagogical", para. 2). This concept joins a growing body of literature that emphasizes how online learning design requires more than the implementation of technical usability strategies and techniques (Zaharias & Poylymenakou, 2009). For example, Zaharias and Poylymenakou (2009) mentioned the direct tie between the usability of e-learning designs and pedagogical value: "An e-learning application may be usable but not in the pedagogical sense and vice-versa" (p. 1). Thus, a learning-centered design paradigm, defined as designing with the purpose of meeting the unique needs of learners (e.g., motivational needs, pedagogical needs, metacognitive needs), has gained a significant role within UX studies (Brna & Cox, 1998).

Designing to improve UX will also contribute to improving pedagogical usability as learning-centered design requires an efficient combination of UX strategies and learning theories (Zaharias, 2004; Zaharias & Poylymenakou, 2009). See Figure 2 for a visual depiction of how UX intersects with both learner experience and pedagogical usability. This chapter focuses specifically on UX rather than the broader contexts of learner experience and pedagogical usability.
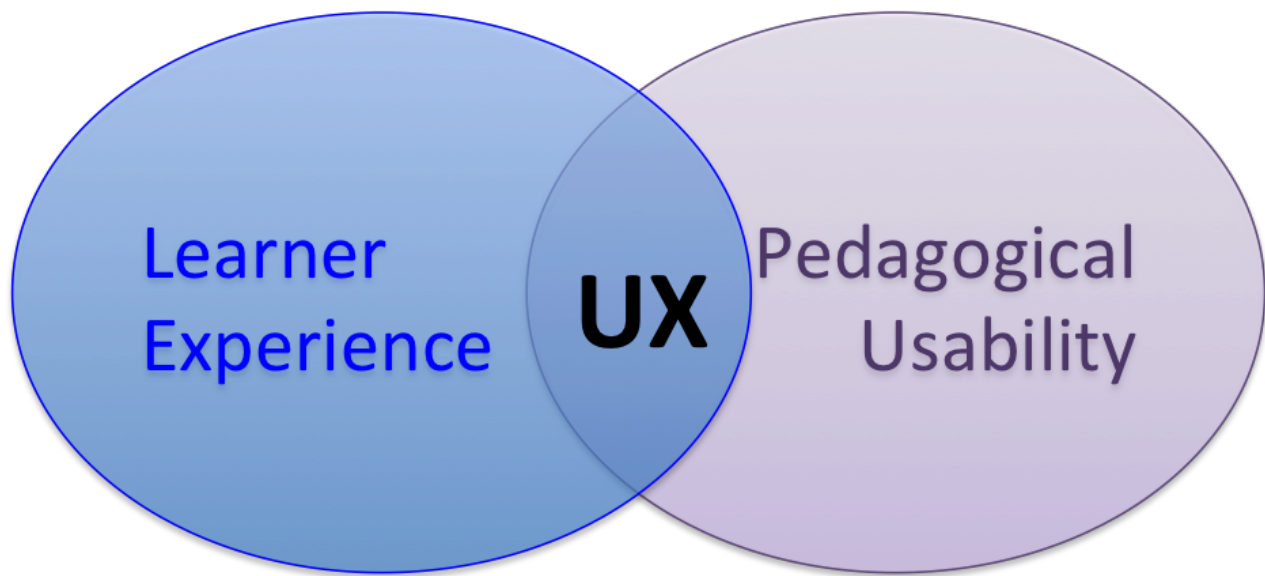
Figure 2

UX at the Intersection of Learner Experience and Pedagogical Usability

3. Think-Aloud Observations Study

The authors of this chapter were all involved in a university-wide LMS transition from ANGEL to Canvas at a university where instructional design is largely decentralized, and multiple design groups work on online courses. The structure, naming conventions, and functionality of Canvas were distinct enough from ANGEL to require transitional design decisions made by instructors and instructional designers across the university. Therefore, the authors, originating from four organizationally distinct instructional design units, collaborated to investigate online courses through a UX lens and executed a TAO study (Cotton & Gresty, 2006) to answer the following research questions: (1) How are students experiencing the UX of online course designs in Canvas? (2) What UX design principles and best practices do these experiences indicate? See Gregg (2017) for the university whitepaper written on this study.

3.1. Study Design

While not specifically a design-based research (DBR) study, our research was very much in the methodological spirit of DBR (The Design-Based Research Collective, 2003) through both intentionally improving practice—by making specific Canvas course designs more intuitive and easier to navigate—and contributing to the broader literature—by identifying UX design principles and methods that could be relevant to others in the field.

Each instructional design unit participating in the study recruited student participants who had taken that unit's online courses. The target was five participants per unit based on usability best practices (Nielsen, 2000). The study went through the institutional review board (IRB), and the participants each signed a consent form allowing their data to be analyzed and shared in anonymized ways. Any participant names used in this paper are pseudonyms. Participants were each incentivized with a $50 gift card on completion of the think-aloud observation; funding for incentives was provided by one of the participating colleges as well as a central instructional technology support department.

In total, 19 participants completed this study. The participant sample included males (12) and females (7); undergraduate (10) and graduate (9) students; and the following age ranges: 18−23 (4), 24−29 (4), 30−39 (4), 40−50 (5), 50−59 (2). Six of the participants had never used Canvas before, while 13 already had some experience in Canvas. While most students were located on or near the university's main campus, one fully online student drove over eight hours to be able to visit the campus for the first time and participate in the study.

3.2. Data Collection

While each instructional design unit used their own course design and recruited their own participants, the study was conducted in such a way that there would be consistency across the data collection. Each unit developed a set of tasks for the participants to complete based on a consistent set of core questions; see Table 1 for examples of core questions.

Table 1

Sample Questions From the Think Aloud Instrument

Task #	Task Description
Task 3	You would like to receive a weekly email notification regarding course announcements. How would you set-up this notification?
Task 4	You remember you have the Lesson 09 quiz this week but need to check the submission due date. How would you find out when your quiz is due?

All of the facilitators, except those from the first instructional design unit participating in the study, received the same training in how to conduct a think-aloud observation. In order to reduce pressure or power differentials that the participants might have experienced, the facilitators explained to participants there were no "wrong" answers or ways to do things and that they themselves were not being tested. As illustrated in Figure 3, each testing room was set up in a similar manner to audio, video, and screen capture the full observation. In each TAO, the participant was greeted by the facilitator, asked to sign the consent form, given a demonstration of how to "think aloud," asked to complete each of the tasks while thinking aloud, rate the difficulty of each task, and respond to a series of open-ended questions. Immediately following each TAO, the facilitators wrote a reflective memo (Saldaña, 2012) capturing their observations of where the participants navigated seamlessly and where they had challenges.
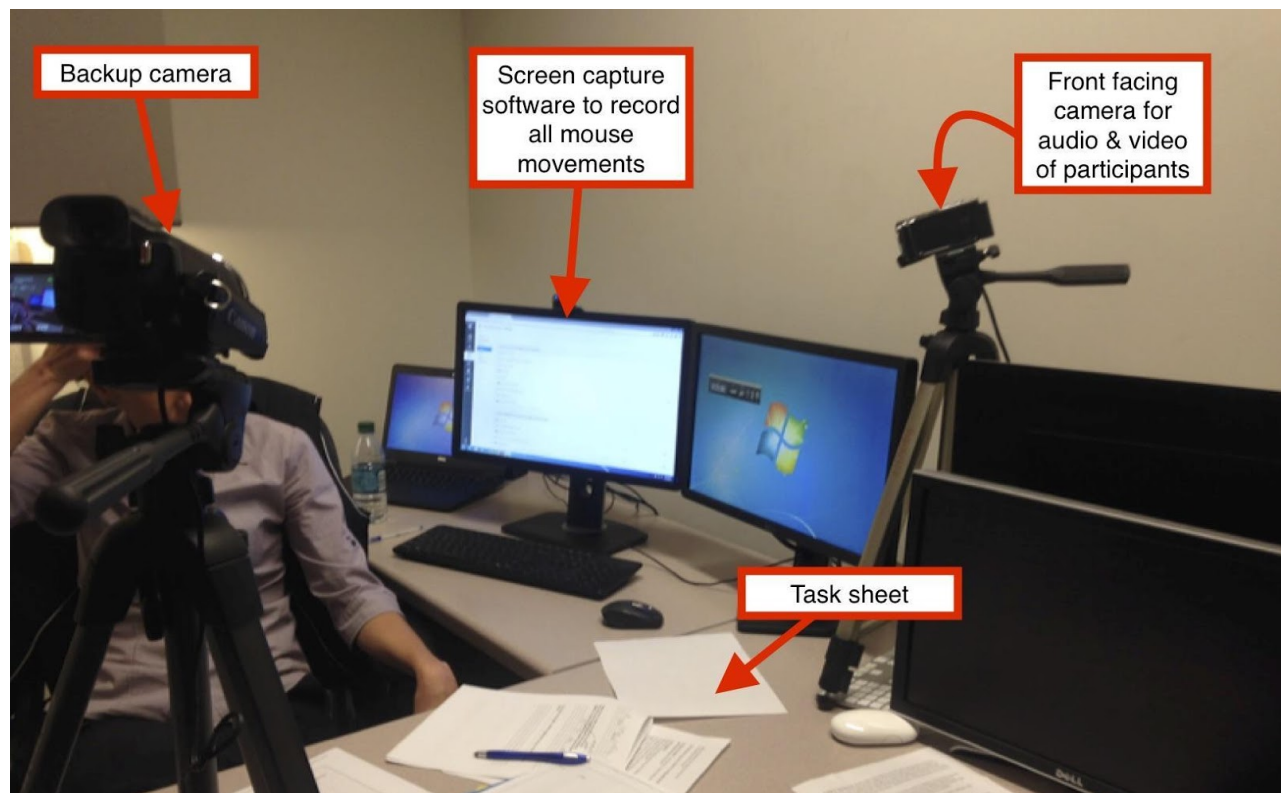
Figure 3

TAO Standard Room Configuration

3.3. Data Analysis

In order to identify patterns in the learners' actual behaviors and experiences, two researchers conducted the data analysis. Data considered were both qualitative—including the facilitators' reflective memos, participant comments, and navigation patterns—and quantitative—including time on task and difficulty ratings. The researchers separately and collectively reviewed the full transcripts of each TAO, videos, difficulty rankings, open-ended participant comments, and facilitator notes multiple times. One researcher explicated all of the steps for each task for each participant and coded for time, effectiveness, efficiency, satisfaction, and learnability, using a scheme developed by both researchers. Effectiveness pertained to the accuracy of task completion, efficiency to the amount of effort and time, satisfaction to how learners responded to the system, and learnability to efficiency gain over time (Frøkjær et al., 2000; Nielsen, 2012; Tullis & Albert, 2013). These data were then analyzed thematically to identify suggested best practice design principles (Braun & Clarke, 2006; Clarke & Braun, 2014; Creswell, 2012; Saldaña, 2012).

To ensure quality, both researchers worked individually and collaboratively with all of the data over an extended period of time, discussed and resolved different perspectives, and developed mutually agreed-upon codes, analysis schemes, and final themes. By way of transparency, it should be noted that one of the researchers was also a participant in the study before she was aware that she would be working on the data analysis. This issue was discussed in-depth, and it was decided that her data would remain in the study as her role as a researcher was not established at the time of her participation.

3.4. Limitations

Limitations of this study include the non-random recruitment of participants due to, with one exception, all participants living near campus. Additionally, in spite of the training across the facilitators, there were slight differences in how each

encouraged thinking aloud. Lastly, there were some tasks with ambiguities in terms of what specifically was being asked of the participant. These were removed from the data.

3.5. Findings and Implications

The following section briefly highlights findings and implications for design practices, specifically pertaining to improving UX, as suggested by the study. Pedagogical aspects such as learning outcomes and instructional design quality are not within the scope of the study. Participant quotes taken from their open-ended feedback during each of the TAOs are provided below to highlight the themes.

3.5.1. Avoid Naming Ambiguities

Unclear wording in a course, whether resulting from ambiguity, similarities (e.g., "unit," "lesson"), naming conventions (e.g., "L07," "Lesson07"), or mismatched terminology (e.g., "groups," "teams"), can become a barrier to seamless navigation. For instance, calling something a "discussion forum" in one place and a "discussion activity" in another can be confusing. As a participant noted, "I think this is the discussion forum. It doesn't actually say discussion forum on it. But it does have a little text box, so I'm going to guess that's what it is . . . Discussion activity is the same thing as discussion forum. That was a little confusing, but it makes sense to connect those two languages then." Additionally, terms that appear similar to participants caused confusion. Maggie demonstrated this confusion among terminology: "The lesson two fundraising scenario assignment, the word assignment seems kind of vague considering there is a discussion forum and an essay. So I don't really—I was confused to which one to choose to submit it in." To maximize intuitive design, use identical terms for the same item throughout the course and sufficiently distinguish terms for different items.

3.5.2. Minimize Multiple Interfaces

When obligated to use different interfaces or systems outside the LMS, learners are required to navigate more than one design. David illustrated this: "You're still using two separate systems . . . That's a lot of the confusion and for a lot of students because you're kind of in two different worlds, back and forth . . . to get back to here, you got to go through the Canvas link and go back, and then it jumps you at the top end and—you're not even within your course anymore, it's a little odd." When evaluating whether or not an interface is needed in addition to the LMS; therefore, designers must compare the additional system's benefits against the UX costs of requiring students to move between multiple systems.

3.5.3. Design Within the Conventions of the LMS

Instructors and designers often develop workarounds to make systems work differently than they were intended and cause confusion for learners. For instance, some course designs use both "units" and "lessons" to organize content. Units are the containers that hold multiple lessons in order to make things easier to navigate; however, this is not always the case. For example, no logical connection was made between the two when learners were navigating the system, as noted by Alan: "It's a little confusing because I see unit three but then there's lesson five, lesson six. Lesson five activity, lesson six activity, lesson seven activity." Gary stated, "I'm in 'modules' and I'm just going to Unit Three—no, that's Lesson Five. What was Lesson Three? Lesson Three is Unit Two, content is right there." To avoid confusion, designers should adhere as closely as possible to the LMS naming conventions and structure.

3.5.4. Group Related Information Together

In this study, students opened multiple browsers to reference information published in different locations and to ensure they weren't missing anything. As Lien put it, "I find sometimes when I was looking for the due time and the assignments of a specific lesson, sometimes I can find part of the information in the Module under each lesson, but sometimes I have also go back to the Course Syllabus to find more . . . I feel like sometimes it's better to put all the assignments, maybe like due time, and what activity, and the name together in one place . . . it's better to save us time and make it more clear." Whenever possible, put related project information in a single location with references linking to that information throughout the course.

3.5.5. Consider Consistent Online Course Design Across Courses

Because of the distributed nature of higher education, universities can include multiple campuses, colleges, departments, individual programs, and many diverse faculty members with unique and discipline-specific approaches to pedagogy. Additionally, there are new approaches to teaching and learning that might intentionally disrupt more standardized approaches. However, usability benefits when there is consistency in UX design across online courses. One participant emphasized a preference for consistency: "I like the fact that when you come to—when you're looking right here at the list of the lessons, you sort of know that the first link will be the lesson directions. And that's good if it's sort of standard across all the classes because—at least that's what I've seen so far." If possible, agree to some consistent UX standards across courses.

This section of the chapter has described the TAO study conducted by the authors and identified suggested best practices for intuitive design based on the experiences of the 19 participants. In the next section, the authors provide an abbreviated guide for others interested in conducting their own TAO study.

4. Suggested Steps for Conducting TAOs with Online Courses

From the beginning of the study, the researchers intentionally positioned themselves as reflective practitioners, wherein they iteratively improved research instruments and processes. They also spent time researching, creating, reviewing, and piloting information and technologies before bringing in actual participants to the facility to test. The following suggested steps for conducting a TAO study were developed through a systematic synthesis of the literature and the critical continuous self-reflections of the authors' experiences with the TAO method. A more detailed version of these steps can be found in Gregg et al. (2018).

4.1. Determine, Pilot, and Do: Conducting TAOs for Course Design

The recommendations for conducting a TAO study are organized in three broad, sequential categories: determine, pilot, and do. First, determine foundational elements, next pilot those elements, and, finally, do the UX testing with recruited participants. Some of the individual steps within each category can be conducted simultaneously or in a slightly different order.

4.2. Determine Foundational Elements

This section emphasizes the multiple areas that should be "determined" early in the process to serve as a blueprint for execution (Farrell, 2017). The first step in designing a TAO is identifying what should be evaluated. Practitioners may want to examine a new or existing course design—or even an individual course content element or assessment. After selecting what to test, specific tasks to demonstrate the usability of those elements need to be written. These tasks should be adequately complex yet feasible for testing for the participants (Boren & Ramey, 2000; Nørgaard & Hornbæk, 2006; Rowley, 1994).

Deciding whom to recruit as participants is a necessary step. In general, research demonstrates that testing five users can help identify roughly 80% of the usability problems in a system (Nielsen, 1993; Virzi, 1992). Additionally, while representative users can be ideal, most important is observing people other than the designers navigating the online course while completing authentic tasks (Krug, 2014).

There are multiple options for how to capture the participant observations and information during testing. These include note-taking, audio, video, and screen-capturing. While important things about the course design will be learned from simple observation, researchers can struggle to simultaneously facilitate, take notes, and monitor the TAOs (Boren & Ramey, 2000; Nørgaard & Hornbæk, 2006; Rankin, 1988). Therefore, research advises to record sessions since a retrospective analysis of the TAO can yield deeper understandings and improve the reliability and validity of the findings (Ericsson & Simon, 1993; Rankin, 1988).

When determining where and when to conduct the test, the use of technologies may impact the room or location selection. For example, the use of external cameras for in-person testing may require more floor space. In this case, a dedicated room also is useful as it will not have to be set up and deconstructed in the testing environment continually. If conducting a more formal study with IRB approval, an informed consent form will need to be signed by the participants. Even if it is not an IRB study, some form of consent should still be gained out of respect for the participants including transparency as to how their data will be used. Also, funding and/or incentives are not required to conduct TAOs, but they can be helpful with recruitment.

4.3. Pilot the TAO Process

Piloting is a very important part of conducting successful TAOs as it provides the opportunity to: (a) rehearse to ensure the study will run smoothly, (b) test the tasks to ensure none are misleading or confusing, (c) establish realistic timing estimations, and (d) validate the data and the wording of the tasks for reliable findings (Schade, 2015).

Do not assume that just because a task scenario makes sense to the person who wrote it that it would also make sense to the participants. If there is misleading wording in the questions, then accurately determining if participant confusion is due to a non-intuitive interface or problematic task questions becomes more difficult. To avoid this type of situation in the TAOs, we suggest asking someone else who is not involved in the writing of the questions to read the question and then describe exactly what the person perceives from it.

As most practitioners know, technology often does not perform as intended. A complete run-through of the technology to be used for the UX testing ideally in the room in which it will be used can help detect any problems with audio and video capturing (Rowley, 1994; Schade, 2015). Practicing in the room itself will also allow the discovery of any potential issues with noise, temperature, and room configuration.

Important things will be learned from simply watching how the participants navigate and where they seem to get confused, but the "thinking aloud" part of the TAOs is especially revealing. After all, Rubin and Chisnell (2008) assert that through the think-aloud technique, one can "capture preference and performance data simultaneously" (p. 204). This strategy can also expose participants' emotions, expectations, and preconceptions (Rubin & Chisnell, 2008).

Thinking aloud while completing prescribed tasks is likely something the participant has not been asked to do before and is a behavior that does not come naturally to most people (Nielsen et al., 2002). Furthermore, asking someone to think aloud, especially while being recorded, can make for a potentially awkward encounter. Therefore, researchers should demonstrate the thinking-aloud process for the participants by viewing a task scenario on a completely different website and then thinking aloud while completing the task. Facilitators should practice helping participants through any nervousness or frustration (Boren & Ramey, 2000; Rowley, 1994).

Finally, in addition to piloting individual elements of the process, we strongly suggest that facilitators practice the entirety of the TAO process. The full pilot will not only reveal potential elements of the testing process to change but may also highlight design areas that can be improved in the course before actual testing (Boren & Ramey, 2000; Rowley, 1994; Schade, 2015). Two elements to include in a process pilot are a script and a checklist. A script will ensure consistency with each participant. The script should welcome the participant, outline the different phases of testing, and include information about how the facilitator may not be able to answer navigation-related questions from the participant during the testing phase. At this point, the script must emphasize that the UX of the course is being evaluated and not the participant. A detailed checklist may include items such as turning on all cameras, making sure the participant has access to the test environment, and having the participant sign any necessary forms.

4.4. Do the Actual UX Testing

Once all of the key elements of the TAO testing have been both determined and piloted, practitioners will shift into the actual recruiting of participants and conducting of the UX tests. Here the key steps in the process of actually conducting the TAOs are highlighted. With a participant audience identified, the next step is to recruit. If non-students

were used as representative testers, then the recruiting process may be as simple as asking a few coworkers to assist. When recruitment is complete, the logistics of scheduling a time for participants to come to the facility for UX testing should occur.

Even when the elements of the TAO testing are determined and piloted, problems may still occur. We suggest keeping Krug's advice in mind: "Testing one user is 100 percent better than testing none. Testing always works, and even the worst test with the wrong user will show you important things you can do to improve your site" (2014, p. 114). With two facilitators, one can be designated to take notes. However, even if there is only one facilitator, brief notes can still be taken during the test itself. In either scenario, we highly recommend continuing to capture thoughts as reflective memos immediately after the testing is complete.

When capturing reflections, document anything that gives context for the particular participant and what is observed related to UX areas. Note both what is observed (e.g., "participant struggled with locating his group") and thoughts about how to make design improvements (e.g., "rename groups for consistency"). The more information captured during and immediately following the testing results in more data for making improvements to the design.

After conducting the TAOs, the next step is to review the collected data—both the recorded testing and the documented observations. Additionally, while this chapter shared details of a more formal data analysis, this is not necessary to make pragmatic UX improvements. Simply having multiple individuals watch the recorded navigation will highlight areas that are not intuitive. Finally, the purpose of conducting TAO testing is to improve course design and the student navigation experience. When determining what to change and improve based on the TAO testing, Krug (2010) recommends a "path of least resistance" approach to what is changed by asking, "What's the smallest, simplest change we can make that's likely to keep people from having the problem we observed?" (p. 111).

5. Conclusion

This chapter has focused on TAO testing as a useful method for improving the UX of online course designs. First, it positioned UX in the broader contexts of learner experience and pedagogical usability. Next, it presented the methods and findings of a TAO study conducted by the authors. Lastly, it provided specific steps for practitioners interested in conducting their TAO testing.

Ultimately, education involves personal challenge, change, growth, and development, no matter the discipline. Furthermore, students are more than simply "consumers" or "users," and teaching and learning is far more complex than a simple web transaction or exchange of money for a service or product. At the same time, online students who are lost in a non-intuitive course interface have a lot in common with users who cannot easily navigate a consumer website. Learners may be less likely to leave a course website compared to a consumer website; however, poor UX design still has learning consequences. One of the biggest barriers to learning and learning satisfaction in the online learning environment is related to technical challenges encountered by learners (Song et al., 2004). Time and energy spent on trying to navigate a poorly designed course interface are time and energy not dedicated to the learning itself.

While instructional designers may want course navigation to be seamless from a UX perspective, they also can work in a vacuum without much, if any, direct UX feedback from students. Additionally, the life experiences of designers may not be representative of their students who take their courses (Rapanta & Cantoni, 2014). Consider that many designers go into the field because they like technology; this interest may not be shared by the average student. Therefore, student feedback on course-design usability assists designers in creating environments for students to focus on the more important elements of the learning experience. As working practitioners who conducted UX testing on their course designs, we have witnessed firsthand the power of student feedback through the TAO method. We would argue that receiving this form of feedback is a crucial element in course design that can help bridge the gap between designer intention and student execution. As discussed in the beginning of this chapter, UX testing is increasingly becoming the norm in industries that rely on web interfaces to reach their audiences. We believe that UX testing should also play more

of a role in e-learning. The framework and discussion here are a part of the efforts to ensure that UX testing plays a stronger role in the field.

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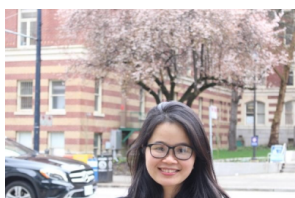
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