Educational Communications and Technology: Issues and Innovations

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Intersections Across Disciplines

Interdisciplinarity and learning

AECT ASSOCIATION FOR EDUCATIONAL COMMUNICATIONS & TECHNOLOGY

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Educational Communications and Technology Issues and Innovations

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Preface

Hosted by the Association for Educational Communication and Technology [AECT], the 2019 Summer Research Symposium was held in Bloomington, Indiana. Twenty-three authors presented and discussed their writing in the 2-day event. The formal topic for this year's symposium was *Intersections across disciplines: Interdisciplinarity and learning design.* Chapter topics ranged from virtual reality interventions for people with autism to investigating and presenting material culture, to working internationally in design. After other peer reviews and edits, the developed chapters are included in this book.

While AECT generally focuses on educational technology and instructional design, the goal of the symposium is to examine a broad range of topics and disciplines. This diversity is well received. Participants of the 2019 Symposium valued the inclusion of different viewpoints and ideas which enriched the experience of discussion and interaction. Those attending include authors from landscape architecture, interior design, and university museums in addition to traditional AECT disciplines.

The AECT Summer Research Symposium began in 2006. A new symposium process was implemented with the 2012 gathering. Originally held in even-numbered years, beginning in 2019 the symposium is being offered on an annual basis.

The structure for the Symposium is quite different from most other conferences and even the AECT International Convention. Rather than presenting research or ideas in a didactic format, in the symposium, authors discuss their ideas in a round table format. In those discussions, every author is able to interact and work with 10–20 other participants about their chapter. This process encourages engagement and interaction among all participants.

Initially chapters are anonymously selected from brief proposals, and authors are asked to develop a subsequent draft. These first chapter drafts are completed 6 weeks prior to the meeting, and all symposium participants, authors and discussants alike, are expected to read and be ready to comment on other chapters.

Development of the included chapters is also different from most journals and conferences, with more engagement throughout the process with the editorial team and among authors. Most of the time, academic authors do not have a regular opportunity for detailed review and critique of their work. While articles are typically sent off to a journal and reviewed remotely, chapters examined through the symposium process are discussed at length, and critical aspects are personally reviewed.

Chapters have been authored by individuals, collaborative teams, or as faculty mentors with graduate students. Each type is usually represented in every symposium. And each adds a richness to the discussion and interaction.

During the symposium, each chapter is discussed in small groups on three separate occasions with different respondents. The other participants, having read the chapter, offer critique and encouragement in the development of the writing. This lasts about half an hour, and after a break, a new group of authors presents their work. Through the course of the symposium, each author or authoring team is involved in conversations with other authors about their work. Anecdotally, authors comment they seldom have the chance to work so closely with peers in the development of their written pieces.

In this focused venue, there are many opportunities to informally interact with other scholars. Discussions about ideas and the writing become very focused and interactive. The working goal of the symposium is to develop everyone's writing to improve the final product. It is the joint development of the finished book. It's no wonder that subsequent collaborations occur among participating authors and non-authors.

The symposium is also open to those interested and who seek to read and discuss new and developing work in the field. Non-author discussants who wish to participate have access to all the first-draft papers and are expected to engage in discussion on the work. These conversations are, in themselves, both intense and informative, as other authors, other participants, and editors all are discussing a given piece. It's common to see experts in the field, other authors, and graduate students all engaged in a conversation around the same table.

The process of discussion is called a "Pro-Action" café and is derived from the processes of Art of Hosting. Art of Hosting (or the Art of Participatory Leadership) is series of methods of structuring and encouraging conversations for planning, idea development, and community decision-making. This allows the authors to engage in intense conversation and interaction regarding their work. In this venue, it is being used to engage discussion among authors and experts.

After the Symposium, authors are asked to improve and revise their article. A second extended draft is due about 2 months after the in-person symposium. That version is critiqued by another author who has attended the symposium and who is already familiar with the writing. Following their response, the author again revises and resubmits a final draft. It's then reviewed by the editorial team two additional times before it is sent to Springer for publication.

This year the editors of five of the AECT journals attended the symposium and also offered their comments on the work. These editors participate for a number of reasons. Their engagement with the process helps advance the principal publication of the symposium, but they also are seeking new reviewers and new authors for their own journals. For example, newer journals, such as the *Journal for Formative Designs for Learning*, seek new reviewers of articles dealing with formative aspects of education. The journals' roles are quite diverse, but given the diversity of writing for the symposium, there is strong potential future journal articles are well represented.

The Symposium focuses on a different general topic each year. The topic must be broad enough to encourage a wide range of proposal ideas, yet specific enough to provide guidance to authors and researchers. Topics are selected to be of interest to the entire field of educational technology and instructional design. Previous years have looked at the use of narrative, design, and learning environments.

Here, we seek to examine how learning and the design of instruction is interdisciplinary and connective both in terms of research and practice. This framework has shaped our interactions, our discussions, and the informal context of the symposium. Writings are solicited on multiple levels including research and practice on learning across disciplines, including instructional design and how design thinking is inherently interdisciplinary. How learning is designed for general audiences or for purposely integrated educational experiences has also been examined. The book is generally divided into three parts: Theory, Research, and Application.

It does take a large team to put together an event like the Summer Research Symposium, and they deserve to be recognized:

Proposal Reviewers

A special thanks is offered to the reviewers for the 2019 Summer Research Symposium. They are:

Ilene Dawn Alexander
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Colin Gray
Phil Harris
Jason McDonald
Amie Norden
Jody Nyboer
Andrew A. Tawfik
George Veletsianos

Interns

Meina Zhu, Indiana University-Bloomington
Ahmed Lachheb, Indiana University-Bloomington

AECT Staff

The symposium has grown with the active support of the Board and administration of AECT. Special thanks goes to Larry Vernon and Terri Lawson for their work and assistance with operating the event. Phil Harris, as AECT Executive Director, has continued to support, participate, run a boom mike, and guide the symposium. Special thanks is offered for their work.

We very much hope you find the contents of this book to be engaging as well as useful for your scholarly endeavors.

Keywords
Research; Summer Research Symposium; Publication; Interdisciplinary Learning

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Contents

Rethinking the Role of the Library in an Era of Inquiry-Based Learning: Opportunities for Interdisciplinary Approaches

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Introduction

Recently, educators have migrated toward inquiry-based learning strategies whereby learners self-direct their own understanding as they solve complex problems embedded within authentic scenarios (Lazonder & Harmsen, 2016; Loyens & Rikers, 2011). These student-centered instructional strategies, often defined as inquiry-based learning, pose some type of ill-structured case to the student and afford opportunities to generate a solution (Herrington, Reeves, & Oliver, 2014; Lazonder & Harmsen, 2016).

While the discussion has often focused on ways to improve classroom instruction, the emphasis of inquiry skills also suggests a change in direction for librarians. Given the importance of self-directed inquiry and information-seeking, libraries are uniquely skilled to support inquiry-based learning. In line with reform efforts in education, the library science field has also undergone dramatic changes as technology catalyzed a transition toward more digital collection strategies (Glynn & Wu, 2003; Kennan, Corrall, & Afzal, 2014). In one recent survey, Cox and Corrall (2013) contend that the following specialties have recently emerged within the librarian domain: "systems librarian, electronic resource librarian, digital librarian, institutional repository manager, clinical librarian and informationist, digital curator/research data manager, teaching librarian/information literacy educator, and information and knowledge manager" (p. 1526). Once again, these specialties have materialized as educational needs have shifted, as well as the changing format of the resources themselves.

The emergence of inquiry-based learning and the changing role of the librarian signal an opportunity to collaborate; however, these changes are often discussed in isolation and irrespective of the other domain. We argue the recent focus on

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inquiry-based learning, self-directed learning, and information-seeking behavior suggests that more interdisciplinary initiatives are required between classroom instructors and librarians. Future discourse is therefore needed about (a) how the migration towards inquiry-based learning requires educators to plan for supporting information-seeking and (b) how librarians create optimal settings for student-centered instruction. To explore this further, this manuscript first describes the theory that serves as the foundation for inquiry-based learning. We then explore the role of the library and detail how librarians are distinctly suited to facilitate this shift to inquiry-based strategies. Finally, we close with a set of recommendations about how to better position the library to support student learning as it relates toward collaborative learning spaces, open-educational resources, and the development of research skills.

Inquiry-Based Learning

One way to support twenty-first-century learning skills is through classroom practices that ask learners to solve contextualized, ill-structured problems (Herrington et al., 2014; Lazonder & Harmsen, 2016). Rather than focus on rote memorization, learners explore the elements of the problem space (concepts, features, and goals central to the problem) as they develop solutions to resolve the issue (Hmelo-Silver, 2013). The generated solutions must also account for the differing perspectives, constraints, and alternatives that are inherent in the problem (Hmelo-Silver & DeSimone, 2013; Jonassen, 1997). Based on situated learning theory, various instructional strategies have been developed, including problem-based learning (Barrows & Tamblyn, 1980; Lajoie et al., 2014), project-based learning (Chu et al., 2017; Wang, Huang, & Hwang, 2016), and others. Collectively, these approaches are often referred to as inquiry-based learning (Loyens & Rikers, 2011). Although variances may emerge in practice, inquiry-based learning generally consists of the following:

- Ill-structured problem
- Case-structured curriculum
- Collaborative learning
- Reflective learning
- Self-directed learning

Given that instruction in inquiry-based learning is student-centered, classroom instructors play a critical role in facilitating meaningful learning during inquiry. Classroom instructors encourage students to generate hypotheses, engage in information-seeking based on emergent questions, and work collaboratively with peer learning groups. However, this shift presents multiple challenges. Despite instructors' initial enthusiasm for inquiry-based learning, studies show instructors struggle to apply problem-solving strategies and related technologies as learners direct their inquiry (Ertmer & Ottenbreit-Leftwich, 2013; Haynes & Shelton, 2018;

Wijnen, Loyens, Smeets, Kroeze, & Van der Molen, 2017b). This problem is further exacerbated given that educators have little professional development when new educational initiatives are implemented (deChambeau & Ramlo, 2017; Thomas & Watters, 2015). If this issue persists, instructors will be ill-equipped to build information-seeking and problem-solving competencies that are essential to a diverse twenty-first-century workforce.

Alignment Between Instructors and Librarians

Much of the discourse about how to improve learning outcomes and apply inquiry-based learning has been situated within the educational domain. However, requirements for successful inquiry-based learning initiatives extend beyond just the classroom. As noted earlier, inquiry-based learning necessitates information-seeking skills as learners engage in the problem representation and solution generation phases (Chu & Wah, 2009; Cole et al., 2013). The migration toward inquiry-based learning thus elevates the library as an essential part of the pedagogical experience. According to Kuhlthau (2010), classroom instructors cannot effectively incorporate guided inquiry strategies until they see that

> … school librarians are vital agents in creating schools that enable students to learn through vast resources and multiple communication channels. Without this expertise, instructors can only minimally accomplish the information literacy requirement of 21st-century learning standards. Collaborations with instructors in a team can create the necessary climate for students to inquire, participate, create and learn in an information environment. (p. 3)

This assertion by Kuhlthau (2010) is being applied in various educational contexts. At the collegiate level, the ACRL Framework (2016) seeks to accommodate the rapid growth of information formats (e.g. - Web 2.0, social media), as well as shifts in the information that is available. Additionally, ACRL Framework represents a transtion toward inquiry-based learning by requiring collegiate learners to situate themselves in an information-driven society in which they act both as consumers and creators of information (Jacobson & O'Keefe, 2014). The new framework also requires corresponding shifts in the way information literacy instruction is delivered and evaluated (Oakleaf, 2014). In addition to changes in higher education, the American Association of School Librarians (AASL) released new national standards for K-12 school library programs composed of six Shared Foundations (AASL, 2018). Inquiry is the first of these Shared Foundations (Northern, 2019) and coincides with the problem-solving focus of both the Common Core (2014) and the NGSS (2013). This focus on inquiry within both school library and K-12 content area standards thus presents a tremendous opportunity for libraries to enhance collaboration with content area teachers.

Strategies to Align Inquiry-Based Learning and Libraries

The digital age has transformed the types of resources, services, and information delivery systems that libraries provide. Library science has begun to apply these principles through initiatives such as Makerspaces, digital libraries, and metasearch strategies (Cox & Corrall, 2013). If librarians are to be "primary agents for designing new ways of learning" (Kuhlthau, 2010, p. 3), a siloed approach will not suffice and more collaboration between librarians and other educators is needed to facilitate instruction. In the following sections, we outline how librarians and classroom instructors can collaborate in terms of the following: libraries as collaborative learning spaces, libraries as access to open-educational resources, and developing research skills.

Libraries as Collaborative Learning Spaces

Rather than see classrooms as the primary location where learning takes place, libraries can be seen as an extension of the overall problem-solving experience. In particular, Williams and Willett (2017) contend that the shared learning spaces afforded by libraries are an opportunity for collaboration, which is critical for learning in ill-structured problem-solving. As in the case of Makerspaces, these collaborative learning spaces allow individuals to leverage tools and technology to create artifacts that represent their newly acquired knowledge. New tools and technologies that allow people to create in a structured environment, including 3D printers and Raspberry Pi kits, provide additional shared resources that support inquiry-based learning (Burke, 2014). Therefore, the inclusion of Makerspaces in academic and public libraries has been suggested as a way of fostering collaborative problem-solving within the library while demonstrating the continuing value of libraries (Barniskis, 2016; Lee, 2017; Willett, 2017).

In contrast to a library strategy that focuses on access to static materials, collaborative learning spaces (e.g. - Makerspaces) align well with inquiry-based learning strategies because they provide students the opportunity to construct tangible solutions. Specifically, libraries that equip the spaces with appropriate resources allow the student to actively engage with modern technology, explore problems, and develop creative solutions with their peers. To date, studies show patrons successfully develop creative skills when actively using library resources for problem-solving. For instance, Harron and Hughes (2018) found instructors that implemented a Makerspace reported improvements in student-centered instruction, application of knowledge, and opportunities to generate artifacts that represent student knowledge. Additional research documents learning outcomes in terms of idea generation (Hinton, 2018; Noh, 2017), collaboration (Barniskis, 2016), reasoning skills (Trust, Maloy, & Edwards, 2018), and professional identity (Baker & Alexander, 2018) when participants were able to employ collaborative learning spaces located within a library context. Therefore, the research suggests that the affordances of the library library uniquely positions it to support the collaborative element of inquiry-based learning.

Despite the initial movement toward Makerspaces, research suggests additional attention is needed to better reimagine the libraries as more comprehensive collaborative learning spaces, especially as it relates to professional development of librarians (Hsu, Baldwin, & Ching, 2017; Oliver, 2016; Peterson & Scharber, 2018). This migration requires that librarians be well-versed in the physical hardware while also being able to facilitate students' inquiry and information-seeking as they use the novel library resource (Buchanan, Harlan, Bruce, & Edwards, 2016). That said, professional development for Makerspace learning is difficult to access and librarians are often dependent upon outside sources to assist patrons with their creative endeavors (Moorefield-Lang, 2015; Peterson & Scharber, 2018). This can lead librarians to feel overwhelmed and "under-prepared to offer skills and content in Makerspace programs or feeling that the role of the librarian is being undermined by expecting them to be experts in so many areas including making, pedagogy, and reference" (Williams and Willett, 2017, p. 8). Future research and collaborative efforts between librarians and classroom instructors are thus needed to best facilitate the implementation of inquiry-based learning (Lee, 2017; Oliver, 2016; Willett, 2017).

Libraries as Access to Open-Educational Resources

Given the emphasis on information-seeking, research suggests that learners in inquiry-based learning rely more heavily on multiple information resources when compared with didactic strategies (Tawfik & Lilly, 2015; Wijnen, Loyens, Smeets, Kroeze, & van der Molen, 2017a). While libraries serve as a valuable source for collaboration through Makerspaces and promoting ill-structured problem-solving, they also provide a wealth of digital educational resources to promote self-directed learning and information-seeking through public domain assets. In years past, the primary core of resources were available in stacks or through digital subscription services. Moreover, these resources were often restricted by existing copyright laws, which required legal permission despite a legitimate claim for fair use. This, in turn, leads to a permission culture that focused on resource protection over open access (Lessig, 2004). However, the digital age has led to increased accessibility of open-educational resources (OERs), which provides a more expansive set of resources for students to access during their problem-solving. Because OERs are generated by the users and not restricted by tradition copyright licenses, OERs also provide an opportunity for students to create their own learning resource as a representation of their learning (Colvard, Watson, & Park, 2018) and share them with the broader educational community.

Prior collection approaches required permission for use, which limited information-seeking and ultimately learning outcomes in problem-solving. In contrast to copyright materials, most OERs are often accessible through a Creative Commons (CC) license that allows creators to designate how their works can be accessed, reused, and distributed by users. For example, if a student creates a medical animation or 3D diagram of a bridge during an inquiry-based learning activity, s/he could share this resource to a wider audience, provided they give credit and place an Attribution-NonCommercial license on the work. Using different CC license options, teachers could work with the library to release multimedia videos or lesson plans into the public domain so that other educators are able to use the resources for their own classroom activities. In doing so, the license options would allow the resource to be copied and edited by other educators while also providing proper attribution of the materials.

Libraries as access to OERs have various implications for both librarians and classroom instructors. In years past, librarians and classroom instructors have often directed students toward the more readily available internal resources that had been purchased by the academic institution. Although Creative Commons has become more popular in recent years among digital libraries, the emphasis still remains on access of existing materials rather than on content creation (Baaki, Maddrell, & Stauffer, 2017). Furthermore, despite OERs growth over the past two decades, many students are unaware of traditional copyright laws and policies. As educators continue to implement inquiry-based learning, librarians can play an active role in educating students on how creators (instructors, students) can use OERs repositories to protect and share their knowledge artifacts developed during their problem-solving. Further exploration regarding development of OERs within library settings promotes critical thinking among new creators while also affording opportunites to share learning resources with the broader educational community.

Role of the Library in Developing Research Skills

In years past, educators have seen the library as curating a set of resources that support their classroom instruction. In that model, the strategy of the library was to identify relevant resources that aligned with the general direction of classroom objectives and make purchases prior to the start of a semester. In many instances, collection management decisions were often made by working with departmental liaisons about which books were required for an upcoming topic. While this approach was designed to facilitate relationships between classroom instructors and librarians, these decisions were often less pressing when compared with other teaching responsibilities (Poole, 2017; Richards, 2018). Moreover, the liaison was responsible for communicating with his/her colleagues, which is also often not a priority for the liaison. Finally, this a priori approach may be inconsistent with inquiry-based learning approach that asks students to dynamically develop and share their own learning resources encountered during information-seeking.

This importance of self-directed learning during inquiry-based learning presents new opportunities for librarians and classroom instructors to collaborate. Given the research that underscores the importance of information-seeking (Loyens, Rikers, & Schmidt, 2006; Weiss & Belland, 2018; Wijnen et al., 2017a), librarians should explore ways to emphasize research skills and evaluation of digital resources throughout the problem-solving activities. Moreover, librarians could espouse strategies that encourage differentiated information-seeking during the (a) problem representation and (b) solution generation phases (Ge, Law, & Huang, 2016). The former requires learners to identify the relevant resources that are central to the problem space, related conceptual space, and causal mechanisms. The solution generation phase suggests that learners apply their newly acquired understanding toward a solution. Across each phase, learners generate answers to questions based on their knowledge gaps (Sullins & Graesser, 2014) and identify resources that answer the questions. When their knowledge is applied, learners will determine the degree to which their proposed solution is viable. If it is not deemed viable, the student will engage in another cycle of problem-solving and information-seeking given their increased understanding of the phenomenon.

Awareness of the information-seeking needs required at different problem-solving phases positions librarians to support student inquiry in unique ways. With the knowledge about how learners iterate problem-solving, librarians could also adopt specialized content collection strategies and cultivate information skills germane to each phase. In terms of the problem representation phase, libraries could explore ways to generate data literacy skills so that the student's search strategies fully considers the array of resources needed to investigate the problem space. After learners initially explore the problem space, libraries could then transition toward information-seeking approaches that allows learners to compare and contrast different perspectives found within the resources. As learners progress to the solution generation phase, the role of the librarian is to promote resources that resolve knowledge gaps, apply their knowledge, and evaluate their proposed resolution. Given that inquiry-based learning strategies often encourage collaboration, they could also explore digital performance tools that afford opportunities to share knowledge artifacts with their peers at each stage. For example, a tool such as hypothes.is allows individuals to annotate digital tools and later circulate their findings as a way to catalyze discourse. Once again, these strategies signify a shift from resource access to one that better aligns with the student-centered and self-directed approaches accentuated in inquiry-based learning.

Conclusion

Hines and Hines (2012) contend that "it is a commonly held opinion among teaching faculty that the average college student lacks sufficient skill and training in critical thinking and information literacy" (p. 19). Many cite evidence that lecture-based approaches may disseminate information from the instructor to student, but these instructional strategies do not position the learner to apply their knowledge toward meaningful problems that practitioners face (Hmelo-Silver, Duncan, & Chinn, 2007; Leary & Walker, 2009; Wijnen et al., 2017a). Through initiatives such as inquiry-based learning, educators are increasingly exploring classroom practices that expose learners to the types of ill-structured challenges that practitioners face. In doing so, many argue that learners are able to learn the content while also generating additional problem-solving skills (Jonassen, 1997; Kim, Belland, & Walker, 2017).

This shift in educational strategies also coincides with changes in library science. In recent years, the usefulness of libraries has been questioned, as seen in the decreased percentage of academic institutions with libraries (U.S. Department of Education, 2014). In response to the changing landscape of collections, many libraries have expanded their access to modern technology and digital resources, as well as acquired the staff to support students' information-seeking behavior. Despite reform efforts in both education and library science, models and theories that purport to improve education are often constructed irrespective of the other domain. Similarly, Kuhlthau (2014) encourages libraries to share their research outside of library "silo" to better integrate themselves into the greater learning culture. A more interdisciplinary approach is thus needed about how those in library science can play a more pivotal role as institutions espouse inquiry-based and twenty-first-century learning principles. Indeed, libraries are uniquely positioned to support the inquiry-based learning needs of learning communities since they have a unique, global view of the instruction provided by institutions of learning (Collins & Doll, 2012; Baker & Alexander, 2018; Miller & Ray, 2018; Passel-Stoddart, Velte, Henrich, & Gaines, 2018). Based on theory and research, we identify three opportunities that align libraries' emphasis on information-seeking with the migration toward inquiry-based learning in education. The first suggestion, libraries as collaborative learning spaces, considers the library from a holistic perspective and how it can afford opportunities for collaborative knowledge building and generation of tangible solutions. Second, a greater emphasis on open-educational resources shifts the strategy from accessing internal materials to one that emphasizes creation and distribution of new knowledge with other educators. In doing so, this affords the learner a platform to generate and share resources while extending the collections beyond the existing subscriptions of the library. Finally, librarians can support students through the development of research skills and information-seeking strategies at specific stages of their iterative problem-solving, namely the problem representation and solution generation stages. These strategies are just some ways in which educators can better collaborate with their library peers to promote inquiry-based learning and better catalyze higher order learning outcomes.

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Guiding Principles for Integrating Disciplines and Practices in Pursuit of Complex and Diverse Learning Outcomes

Dennis W. Cheek

Interdisciplinarity and Its Alternatives

August committees of experts across organizations and sectors have registered the importance for all human beings to be able to work easily and well across disciplines while using various skills and techniques in concert with other learners (Bear and Skorton, 2019; Daugherty and Carter, 2018; Group for Research and Innovation in Higher Education, 1975; Skorton and Bear, 2018). At the core of these dispositions and behaviors is a need to understand some disciplines in considerable depth as well as having at least a passing familiarity and welcoming attitude towards knowledge, methods, and insights from disciplines far removed from the ones in which a learner has concentrated in their formal schooling. It is worthwhile to pause and ask: What do we mean by "interdisciplinarity" and what, if any, are other alternative ways to consider the relationships between and among various areas of human knowing?

Interdisciplinarity has been defined in many different ways going back to classical times and the ruminations of Greek and Roman writers and philosophers. The ancients formulated various schemas to relate forms of human knowing to one another and to goad, coax, and interrogate an (almost always) male learner to seek not just knowledge but, more importantly, wisdom. They also argued much among themselves about the hierarchy of various subjects and their relative merits (Marrou, 1964).

We have long passed the time when a single human being could dare to claim, as Francis Bacon wrote to Lord Burleigh in 1592, that "I have taken all knowledge to

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be my province" (Bartlett, 2002: 165). Curriculum specialists and philosophers have continually wrestled with questions about what knowledge is worth studying given that time is the most precious of all human resources (Whitehead, 1929). How should such studies be arrayed? Who can or should teach such subjects to learners? How should learners progress through these studies? How should they demonstrate their mastery?

Various means of integrating subjects within formal schooling have been ongoing enterprises across time, geographies, nations, and languages – a practice which has ebbed and flowed and shows no sign of abating. These include numerous concepts such as interdisciplinarity, multidisciplinarity (or pluri-disciplinarity), and transdisciplinarity for which multiple competing definitions exist (Akçeşme, Baktir, & Steele, 2016; Frodemon, Klein, & Pacheco, 2017). Various ways of integrating the curriculum itself can be grouped into three broad categories: that which occurs *within* single disciplines, *across* several disciplines, and within *and* across disciplines (Blandow, 1993; Cheek, 1993, as applied to technology and design education and more generally, Peirce, 2009; Frodeman, Klein, & Pacheco, 2017).

The realm of higher education since the origins of universities in medieval Europe has been filled with these discussions and experimentation about the "best" ways to organize faculties, represent knowledge, undertake research, form the next generation of the professorate, and increase the reputational capital and prestige of different subjects over time (Clark, 2006; Kerr, 1964; Lucas, 2006; Newman, 1852/1982). Interdisciplinarity has waxed and waned in its acceptance, practice, and promotion – all the while with seemingly inexorable forces continuing to spawn new hybrid subjects which eventually become their own acknowledged disciplines (Barry & Born, 2014; Green, 1980; Kockelmans, 1979; Power & Handley, 2019). Governments have also been heavily involved in the promotion of interdisciplinary efforts (cf. Committee on Facilitating Interdisciplinary Research, 2005; Jacobs, 2013; Klein, 1990, 1996; Kline, 1995; Newell, 1998). Some academics have taken insights from research within a single scientific discipline, such as quantum physics, to suggest that since reality can coexist on multiple levels, only a transdisciplinary approach can deal effectively with the dynamics of the multiple levels of reality that physicists suggest we inhabit and that transdisciplinarity is therefore essential to all significant learning (Nicolescu, 2002). It has been suggested that even research prizes, like the Nobel Prizes in the sciences, should adjust to this new reality in terms of making place for the consideration of scientific work that crosses many disciplines or is not easily categorized into any of the existing fields for which Nobel Prizes are awarded (Szell, Ma, & Sinatra, 2018).

Two Complementary Taxonomies for Human Competencies

Specialized labor within modern societies has led to various specialized forms of knowledge, techniques, skills, and educational programs (both formal and informal) to prepare workers for selected fields and professions. The U.S. Department of

Labor, Employment and Training Administration (DOL) has worked with its partners for a number of years to empirically identify the needed job proficiencies, dispositions, and skills for the twenty-first century. The CareerOneStop, sponsored by the DOL, has a Competency Model Clearinghouse that employs a Pyramid Building Blocks that includes standardized elements for all jobs (Tiers 1, 2, and 3) and Management Competencies that all managers employ across the diverse organizations in which they serve as managers (see Fig. 1). This systematic process of identifying and tracking the use of such skills, knowledge, and dispositions in actual jobs involves the use of empirical observations by independent and highly trained observers, journaling by individuals within given job assignments, and compilations of data and insights drawn from human resources departments, managers, tests routinely administered in particular job fields, and specialized labor reports and empirical research by academics from a wide variety of fields.

Tier 1 competencies, the lowest level of the pyramid, focus on interpersonal skills and dispositions that are deemed essential for all workers as well as managers. Tier 2 focuses on academic competencies that span the arts, sciences, technology, and humanities coupled with thinking, communication, and basic computer skills.

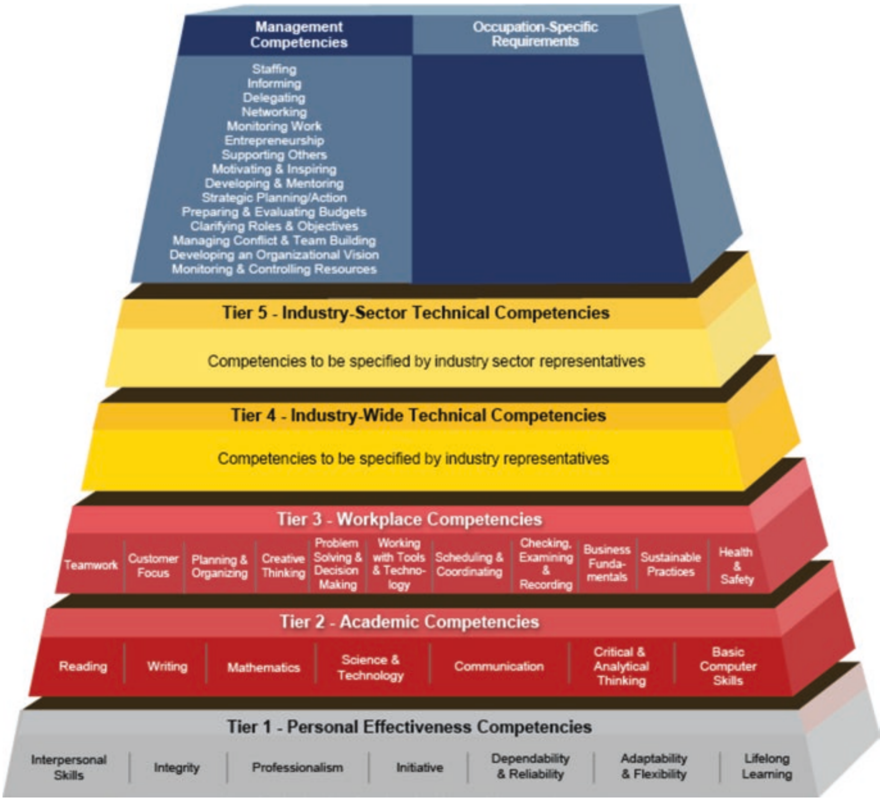

Fig. 1 Pyramid Building Blocks Model for US jobs, U.S. Department of Labor

Tier 3 focuses on workplace skills needed for all workers and managers: Here we especially highlight creative thinking and problem-solving and decision-making skills as well as team skills, which would include creative thinking, problem-solving, and decision-making within groups which require more advanced abilities beyond those for thinking and problem-solving solely for oneself. The DOL has large amounts of qualitative and quantitative data within O*Net that support a core set of management skills and competencies that all managers must possess for the twenty-first century. In addition, they have left open a set of occupation-specific requirements for managers within distinct industries or within the sectors which make up that specific industry.

O*Net comprises the world's largest collection of comprehensive data upon which to derive competency-based models for learning that is related to specific occupations or occupational categories. Various industry sectors are increasingly filling in the appropriate technical competences for their respective fields as well as occupation-specific requirements for certain types of jobs using this innovative Pyramid Building Blocks Model.

A different way of organizing one's own thinking as a learning designer is to consider what specific acts you wish the learner to engage in and how habits (dispositions) of mind and affect interact as its own arena with three other large arenas which can be designated as acquiring information, applying knowledge, and constructing meaning (RI Department of Elementary and Secondary Education, 1995). Within each of these four broad arenas, there are various subcomponents, some of which can be clearly cross-walked to the U.S. Department of Labor efforts regarding specifying job competencies. A more generic form of this work originally undertaken by the author in 1994 appears here as a newly christened "taxonomy of learning capability sets" (Table 1). This taxonomy is not intended to be exhaustive at the level of the descriptors found under each proficiency. It merely illustrates a range of alphabetically arrayed behaviors that could be the kinds of actions and outcomes that learning design practitioners hope to invoke through their designs. Teachers can identify where they are on this taxonomy at any given point within a learning environment. This heuristic tool can also aid more purposeful coordination of learning experiences to achieve more complex learning outcomes. It can help students know where they are among the arenas of acquiring information, applying knowledge, and constructing meaning at both personal and group levels and to exercise more effective control over their own learning.

This approach is complementary in many ways to the job-specific approach of the DOL as it focuses on the ways in which knowledge, skills, dispositions, and settings dynamically interact within learning environments. It also emphasizes the ways in which individual and group processes affect both the dispositions and the behaviors of individual learners. Formal learning systems almost completely neglect specific attention to these foundational habits of mind and affect (Table 1). It can be surmised that the lack of explicit attention to these matters within formal learning systems may greatly diminish the effects of efforts singularly focused on developing the arenas of competence alone and in isolation.

Table 1 Taxonomy of learning capability sets[a]

ACQUIRING INFORMATION ARENA	CONSTRUCTING MEANING ARENA	APPLYING KNOWLEDGE ARENA
Experimental Proficiency Controlling variables Defining in operational terms Following a planned action sequence Formulating/testing hypotheses Framing experimental question Identifying variables Observing Replicating Suggesting improvements Verifying information	Manipulating Information Applying statistical procedures Classifying/developing a key Connection to previous knowledge Developing generalizations Distinguishing Identifying patterns and relationships Inferring Interpreting/evaluating Questioning	Problem Solving Proficiency Clarifying nature of the problem Implementing/verifying solutions Recognizing problems Setting a problem-solving goal Proficiency in Reaching Decisions Assessing the worth of information Building consensus Defining and identifying alternative Developing criteria for comparisons Evaluating probabilities Mitigating conflicts
Mathematical Proficiency Displaying data Estimating Measuring Numeration Performing calculations Language Proficiency Active listening Designing/using surveys Explaining to others Interviewing Locating/using information Translating Writing reports Psychomotor Proficiency Creating visuals Manipulating materials Recording data Using instruments/tools Utilizing computers	Developing Explanatory Frameworks Attempting refutations Creating/testing mental models Creating/testing physical models Generating novel ideas Linking concepts/principles Making testable predictions **FOUNDATIONAL HABITS OF MIND AND AFFECT** Personal Habits Evaluating Identifying bias Knowing one's strengths/weaknesses Monitoring Recognizing one's presuppositions Reflecting Group Habits Building rapport Communicating ideas/information Delegating tasks Identifying group goals Negotiating/compromising	Proficiency in Informed Action Describing costs and benefits Describing current practice/policy Identifying intended consequences Identifying unintended consequences Implementing/fine-tuning action plan Involving key participants Recognizing level and types of uncertainty Proficiency in Making Products Building/testing/refining prototype Constructing desired product Creating desired quality & quality Developing safety features Ensuring desired performance Gathering appropriate materials Real-world testing and refinement

[a]Adapted from my original work in the *RI Science Framework*, Dennis Cheek, Editor-in-chief. Providence, RI: RI Department of Elementary and Secondary Education, 1995, chapter 3, page 4 (ERIC ED445886).

Many other schemes and ways of arranging learning experiences and outcomes exist. We focus here on these two distinct examples which can be easily related to one another and which suggest the many dynamic, chaotic, and serendipitous ways in which skills and knowledge interact during learning and in the course of one's work, social, and personal life.

Learning Environment Principles

In addition to human competencies, learning designers are always also working within the larger context of the learning environment where they find themselves. The Educational Research and Innovation Department of the OECD in Paris has for a number of years created, tested, refined, and developed materials consistent with a set of innovative learning principles. These principles have been commented upon and used by various formal learning organizations in multiple OECD countries to good effect (OECD, 2017: 22–26):

1. *The learning environment recognizes the learners as its core participants, encourages their active engagement and develops in them an understanding of their own activity as learners.*
2. *The learning environment is founded on the social nature of learning and actively encourages well-organized co-operative learning.*
3. *The learning professionals within the learning environment are highly attuned to the learners' motivations and the key role of emotions in achievement.*
4. *The learning environment is acutely sensitive to the individual differences among the learners in it, including their prior knowledge.*
5. *The learning environment devises programmes that demand hard work and challenge from all without excessive overload.*
6. *The learning environment operates with clarity of expectations and deploys assessment strategies consistent with these expectations; there is strong emphasis on formative feedback to support learning.*
7. *The learning environment strongly promotes 'horizontal connectedness' across areas of knowledge and subjects as well as to the community and the wider world.*

First, we can note that these principles reflect the synergy among habits of mind and affect, programs, and individuals within those programs. They highlight the importance of both intrinsic and extrinsic motivation and the important role of prior learning, regular feedback, clear expectations, social learning opportunities, and adequate supports (or affordances) within learning environments. Second, the successful work of OECD suggests that the possibility of universal principles exists at least at a meta-level sufficient to guide R & D efforts across multiple cultures, countries, geographies, and sociopolitical systems.

Practicing 360 Innovation

We now look at how the concepts of interdisciplinarity, the two taxonomies of competencies, and the learning environment principles have been applied within the context of the design and delivery of an intensive graduate-level course module on "Practicing 360 Degree Innovation" within an elite French business school. The students are earning either a Master of Science in Management or a Master's in International Business and come from over 90 countries. The course is taught in English to two different cohorts of students in Paris and Lille (France) in back-to-back weeks.

Thirty to 45 students in each cohort are randomly assigned to one of nine teams. The teams engage in an intense 4-day role-playing simulation that requires them to work in teams. Initially, we collectively as teams work on and adopt a student-crafted, working definition of "innovation" for the course. We next engage in a series of small set tasks focusing on recognizing examples of innovation from within their own respective cultures/nations/languages. Teams also briefly engage in a "competitive" task of redesigning the classroom itself in ways they believe, if executed in the business school, would further maximize learning experiences for students. They share their respective team insights with the rest of the teams both orally and visually. Next, they take a brief collective field trip with the instructor to nearby locations where they are brought to a halt at two or more locations with the assignment of finding one thing within their line of sight that can be further innovated by their team. Each team uses a brief "cascade" technique to build on the initial idea and further expand or improve it.

The few remaining minutes of the first class and afterwards, at their discretion, are spent with each team identifying a local business, NGO, public area, or open space which they will now "own" or "control" as an entity. They are geographically limited to a set region within the environs of the business school building but covering a considerable number of possibilities. For Paris, it is anything found within La Défense, a large area just west of the Paris city limits which is home to most of the larger companies of France and many international companies, universities, shops, government entities, and private residences. For Lille, they are limited to the entire area of Vieille Lille ("Old Lille") which is filled with shops, public areas, historic monuments, historic buildings, government buildings, churches, private residences, etc. They use an "innovation brief" document that employs a framework supplied by the professor to construct a task for another team to complete where they have to provide one or more required innovations for the organization/entity in question. The next day each team is placed into a triad and each innovation team receives their innovation assignment from another client team. They ask pertinent questions of the client and the third (nonactive) team at this point listens in on the conversation. Through a round-robin format, all teams are both a client and a consulting group that is responding to the needs of a client. They are thus aware of three total projects going on within their triad. Days three and four are spent entirely on this assignment, including team visits to their respective innovation sites and ongoing work in afternoon and evening hours. Teams report that they were highly motivated to succeed at these challenging, locally based practical innovation tasks.

Each innovation team meets with their client on the morning of the fourth day to give a presentation (they share preliminary materials via electronic means with their client and simultaneously with the professor, the evening before their presentation). All clients critique the presentation, ask further questions, and make further demands of their innovation teams. Once again, the "inactive" team at any given point listens in on the other presentation and Q & A that transpires between a client and an innovation team.

Following the end of the course, each individual student must assign grades for themselves, each member of their own team, and their own team in its entirety and the two other teams as a whole within their triad. They also write and submit a 500-word reflective essay concerning what they have learned about innovation, working within a random-assigned team, and about themselves during this 4-day simulation. All teams also submit the final version of their consulting team innovation project to the professor. This final product is responsive to the feedback they received from their client as well as including their own improvements independent of the client's prodding or request.

Final grades are comprised of 85% for the role-playing simulation (with 50% of their grade in this portion coming from themselves and fellow students for the consulting innovation projects initial phase and 50% from the professor who grades both initial and final innovation projects) and 15% which is based upon their reflective essay and successfully giving all required grades with rationales for each grade they assign.

Assessing Competencies Engaged and Design Principles at Work

The design of the course itself, the manner in which learning was actualized, challenges that students themselves felt they faced and overcame, and emergent self-understandings about innovation, work-based competencies, and the impact of the learning environment itself have been documented throughout the 4-day simulations and resultant work products by students and teams. The following competencies and design principles enunciated above seem to be readily apparent during the course and are reinforced by the work products produced, the conversations engaged, the grades and rationales for those grades given, and the insightful self-reflective essays produced by students. Sample comments from students highlight the impact of a few elements:

Pyramid Building Block specifically engaged:

Tier 1: Personal Effectiveness Competencies interpersonal skills, integrity, professionalism, initiative, dependability and reliability, and adaptability and flexibility. *"It was genius to work in mixed teams where everyone has a valuable input to* *contribute within the project. It can become crazy and overwhelming at a certain point because practically it is exhaust[ing] to accept the difference[s] of personalities and points of views but you figure out a way to handle it as the deadline gets closer. While working with my team I learned that differences can actually result in something innovative and never exist[ing] before."* (Student C)

Tier 2: Academic Competencies writing, communication, critical and analytical thinking, and basic computer skills. *"… this course gave us the tools to identify opportunities for innovation in a local environment with a [brief] amount of time, and while addressing the necessities or parameters of a client. It was really interesting not only to be given a specific task by a group (to come up with a creative idea), but also to create our own parameters and set goals so that another team could execute it. I learned about myself that you need to be prepare[d] in life to handle this type of situation where you are given a 'problem' and you have to solve it in a finite amount of time and in a positive/creative way."* (Student I)

Tier 3: Industry-Wide Technical Competencies Students drew upon relevant business knowledge of marketing, branding, finance, strategy, human resource management, entrepreneurship, and innovation. *"I had been considering myself as 'not [a] creative person' so I was not willing to think about innovation…. [yet] innovation skill is necessary, especially for a business person …. Thanks to this course I could change my mind towards innovation …. we have done real-case projects which are not just academic but also practical. The insight also makes me realize that there are many opportunities for innovation even in daily life."* (Student H)

Tier 6: Management Competencies informing, delegating, networking, monitoring work, entrepreneurship, supporting others, motivating and inspiring, preparing and evaluating budgets, clarifying roles and objectives, and managing conflict and team building. *"This project allowed us from my point of view to work in a team more 'professional' than usual … Finally, I found interesting the accountability system for students. I appreciate the fact that students have a say in the performance of other groups and have a concrete impact on everyone's grades. This allows us to be more attentive to the projects of others and to really be interested in their proposals. The fact that we have created the subject for another group reinforces this sense of involvement in the course." (Student F)*

Rhode Island Science Framework Arenas of Competence specifically engaged:

Foundation Habits of Mind and Affect personal habits and group habits. *"Within four days, I have learned that understanding each other's strengths and weaknesses, as well as perceptions, are significantly important when it comes to the team-working project …. transparency is one of the key success factors when it comes to team projects. Everyone should consume the same amount of information and we should utilize the proper tools to be able to access the information that everyone shares. In this way we can reduce the information gap and we will be able to stay* *on the same page which enhances the quality of group work. Moreover, listening skill is the skill which everyone should cultivate because by listening to one another efficiently, we can develop the idea in a more innovative way…. many times [an] innovative idea is born when people share different backgrounds and skill sets [and] share their knowledge and fusion their ideas into one. What is more, we should not forget the danger of both bounded rationality and the path dependence because these tendencies could become a tumor of the innovation."* (Student D)

Applying Knowledge Arena problem-solving proficiency, proficiency in reaching decisions, and proficiency in informed action. *"The best innovation come from collaboration, teamwork, and participative approaches. To foster innovation within a team, it is very important to reinforce at all levels … an environment of trust, open communication and support as we did in our group when we were working on our innovative project … Innovation is 'thinking outside the box' so it is important to know that the first step is to be aware that we are in a 'box.' … facilitation skills are very important in order to bring together and then narrow down the ideas of the team. So, the team has to be composed of members who have interdisciplinary and multifunctional skills and knowledge in order to be innovative. The opinion of each counts and when we are in an innovation process, there are no illogical or stupid ideas. Finally, this course taught me that we can't do innovation alone. For innovation, we need new partners and tools. Thus, it is important to have an interdisciplinary team with different backgrounds in order to maximize the process of innovation."* (Student K)

Constructing Meaning Arena manipulating information. *"I had been considering myself as 'not a creative person' so far; I was not willing to think about innovation … Thanks to this course, I could change my mind towards innovation …. innovation can be done by anyone by finding possible improvements… The insight also makes me realize that there are many opportunities for innovation even in daily life …. I find myself trying to find possible improvements more in everyday life. In other words, now I am more aware of innovation."* (Student H)

OECD Learning Environment Principles There is good evidence that all seven of the principles were explicitly found in the learning environment that was created for this course. *"One thing I learned from this course is that when we pay more attention to the little things around us, we will find a lot of opportunities to innovate and make society better…. this small exercise gave me some hints. First, set the clear vision first and do all the innovation related to it. Second, do the innovation based on sustainability… Once we have a vision, which is like having a compass, we then know what the next step is we can do. If we are lost in the middle of the project, just look back to the vision. Do something related to it, and then we will find our way."* (Student L)

"I have learned that there is always room for innovation in every invention, service, location or public area. Indeed, the way of teaching this class itself is an

innovation. For instance, the traditional way of teaching enables only the professor to evaluate the students. However, in this class evaluation is done by the colleagues and by the professor which gives a precise evaluation about the teamwork and the final deliverable to the professor. This way of evaluation encourages teammates to work more productively and seriously as their grading depends also on their classmates which is not the case for other classes…. Another lesson I have learned during this class is that working in randomly assigned teams is crucial…. If the work was with people that we know and [we] share the same background, opportunities for learning are too small. It is true that working with people that we are used to makes us less stressed and more comfortable, however, this can make us procrastinate as well. In addition, presenting to our peers and getting feedback from them enabled us to know our weaknesses in a smoother way. Indeed, the professor was not there when they gave us feedback which made them more at ease while criticizing the project… I believe that innovating the way of teaching is crucial to make the quality of education better. Another part of the course that I found interesting are hints given by the professor during the [opening] lecture. First hint was about presentation of projects to clients. For instance, the professor suggested that the work should be done ahead of time and the presentation should be sent to the clients before presenting the work to them. This will lead to having interesting suggestions and leads to more attention and engagement by the clients. Another hint was about the way of presenting [our projects]. Indeed, the posture, the [use of] silence, and the way of using body language is important to show enthusiasm and the confidence level of the person speaking." (Student M)

Conclusion

A well-designed environment for learning can promote rapid improvements in students' self-efficacy, performance, and insight and increase their desire to engage. Reasonably robust, practical innovations for a variety of local entities were designed by student teams serving role-playing clients within just a few days. When designers make ambitious learning outcomes and designs transparent, students rise to the challenge while also realizing that these are techniques that they can apply in their own roles as leaders and makers of change within the world that we will not live to see.

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Educology Is Interdisciplinary: What Is It? Why Do We Need It? Why Should We Care?

Theodore W. Frick

Introduction

Learning is a phenomenon that occurs across various domains of knowledge. Learning further spans disciplines that are formally focused on learning—including psychology, brain science, educational psychology, education, learning and instructional sciences, and instructional design.

Learning is a phenomenon that even spans biological species. Not only can human beings learn, but also dolphins, dogs, and donkeys.

Furthermore, what is the difference between learning and education? Between education and schools? Education and professional training on the job? Learning and human performance improvement?

We have different words and phrases—let alone expressions in different languages and cultures—that can mean the same thing. Worse, the same word can have different meanings, depending on the context in which it is used. Then consider fake news, outright lies, propaganda, and falsehoods—in contrast to truth (e.g., see Kakutani, 2019).

How can we sort this out? We need an interdisciplinary field that spans various specialized domains of knowledge and that is well-defined. What we need is *Educology* (Frick, 2019; Steiner, 1981).

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Overview

I am using italics to identify terms in this chapter that are defined more precisely than common usage would typically indicate. I have created a growing and evolving website which provides a glossary of proper terms, definitions, and examples of *Educology* at https://educology.iu.edu/index.html (*Educology* Website, 2019). The intent of this *Educology* Website is similar to *Stedman's Medical Dictionary* (Stedman, 2006) and *Terminologia Anatomica* (FCAT: Federative Committee on Anatomical Terminology, 1998) which define terms used in medical science, anatomy, and physiology. This chapter presents an abridged description of *Educology*, which is more fully explicated in Frick (2019). The definitive resource is the *Educology* Website, since it is updated as needed.

In this chapter I first introduce *Educology*, making the distinction between *knowledge* and *education* itself. I then discuss the importance of universal terms for providing the foundation for *Educology*. Next, I distinguish eight kinds of *learning* (*accidental*, *guided*, *intended*, *conducive*, *discovery*, *disciplined inquiry*, *compelled*, and *induced*) and four kinds of *education* (*ineffective*, *effective*, *effective yet bad education*, and *worthwhile education*). I further explain the difference between *educational theory* and *Educology*. Next, I address the questions: Why do we need *Educology*? Why should we care? I conclude by addressing the question: How do we move *Educology* forward?

What Is *Educology*?

Educology is "*knowledge* of *education*" (Steiner, 1981; Frick, 2019). This is a highly important distinction. *Knowledge* is not the same as the *object* of that knowledge. *Education* is the object, what is represented by *knowledge*, which is "recorded *signs* of *knowing* about *education*" (https://educology.iu.edu/knowledge.html). That is why we need the new term, *Educology*, to distinguish the recorded *signs* from their object, *education* (Frick, 2019; Steiner, 1988). In *Educology*, *education* is defined as *conducive learning*. That is, *education* is *intended* and *guided learning* (https://educology.iu.edu/education.html). A *teacher* is one who guides the *learning* of another, and a *student* is one who *intends* to *learn* from that guidance. *Learning*, in turn, is defined as "the increasing of *complexity* of *mental structures*" (https://educology.iu.edu/learning.html). *Complexity* and *mental structures* are further defined, respectively, at https://educology.iu.edu/complexity.html and https://educology.iu.edu/mentalStructure.html.

Without *Educology*, educators and others will continue to talk past each other. The language we typically use in talking about *education* is imprecise, and so we literally often do not understand what each of us is talking about—because the same words refer to different things. For example, you are talking about a *student*, meaning she or he is a young person who attends a school or university, and I am thinking about a *student* as being a person who intends to *learn* under the guidance of another—she or he does not have to be in school or college, nor young, nor inside a building, nor guided by a state-licensed *teacher* or a college professor. We may both use the same words, *student*, *teacher*, and *learning*, but we mean different things.

Unfortunately, we may think we are talking about the same thing, when in fact we are not. This kind of miscommunication and inconsistent use of terminology hinders advancement of *knowledge* in the field of *education*. You do a research study on *student learning* and find one result. I do a study on *student learning* and find a different result. Whose results should we believe? But we may not even be talking about comparable *students* or comparable *learning*. *Learning* is yet another term that needs clarification.

It is as if you are studying cooked oatmeal with added sugar (sucrose) and I am studying cornflakes with added high-fructose syrup. But we both call them sweetened cereals. This clarification is important because fructose is metabolized differently than glucose in the human body. Fructose is effectively a chronic toxin that when metabolized rapidly in significant amounts repeatedly over time can lead to diseases that include type 2 diabetes, atherosclerosis, and cancers. See, for example, Lustig (2009, 2017), McKinley, O'Loughlin, and Bidle (2016), and Taubes (2016).

It is as if in physics mass and energy meant different things to different people—a wide range of misconceptions. For example, some people think of mass being associated with how big something is and how much it weighs. Not so, as it turns out, in the field of physics. Mass is different from weight. An astronaut living in the space station that orbits the Earth has zero weight and appears to just float in the air. Yet the same astronaut standing on a scale in the doctor's office on Earth weighs 130 pounds, or about 59 kilograms. Her mass has not appreciably changed. Just orbit the Earth at about 17,600 miles per hour, and we will weigh nothing. And there are some new terms: pounds, kilograms, miles, hours, and the implied concepts of velocity, force, acceleration, and gravity.

As a further example in *Educology*, the difference between schooling and *education* clarifies what we are talking about when we lament problems we see in our schools, and what to do about these problems. Unfortunately, some schools are not *educating* because those who are taught are not *students*—that is, they do not *intend* to *learn*—as is discussed below.

Universal Terms

In *Educology*, terms are defined as universals. A *universal* is not limited to time or place. For example, the definition of *education system* is not restricted to existing education systems in the USA in the twenty-first century but applies to all education systems—including those in the future as well as those in the past—that could be located anywhere.

In development of *Educology*, it is important that our terminology consists of *universal* classes (Steiner, 1988). A *universal sign* is defined as a "*symbol* whose object is a *universal* class not limited to time or place" (see https://educology.iu.edu/universalSign.html). As an example, in another discipline, when we refer to adipose tissue cells in physiology and anatomy, we are signifying a class of cells in *Homo sapiens* in general, not just in Socrates' body about 2500 years ago, now, or in humans in 5000 A.D., whether here on Earth or elsewhere.

What Is *Education*?

Education is *conducive learning*, which stands in contrast to *compelled learning*, *discovery learning*, and *accidental learning*. Conducive learning is "guided learning and intended learning," which meets Steiner's (1988) criteria for what constitutes the universal class, *education*. These essential relationships are further illustrated next and by Venn diagrams on the *Educology* Website: https://educology.iu.edu/index.html. Figure 1 illustrates relationships among important concepts, in order to separate *education* from other kinds of learning.

Key concepts from which definitions of types of *learning* are derived from this Venn diagram are further illustrated by specific shadings in Venn diagrams in Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14. (These 14 figures are reprinted with permissionfrom Frick (2018) and https://educology.iu.edu.)

What is important to note is that these terms are well-defined. For example, effective yet bad education is "*instrumentally good* but not *intrinsically good education*" (https://educology.iu.edu/effectiveBadEducation.html). In other words,

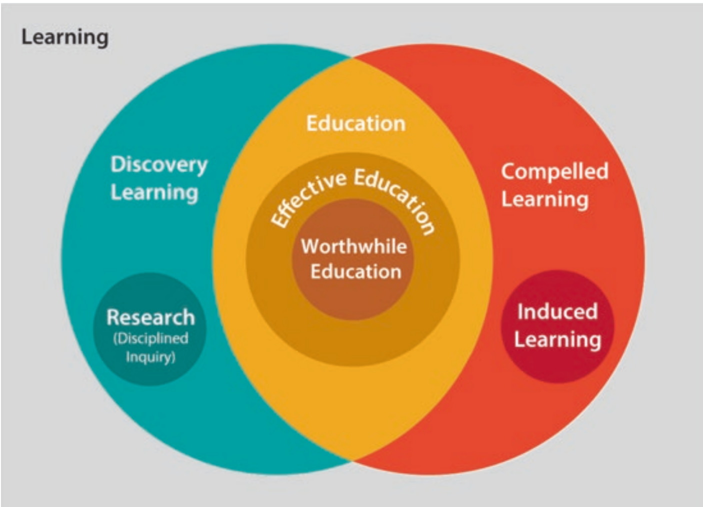


Fig. 1 Venn diagram of kinds of learning and education

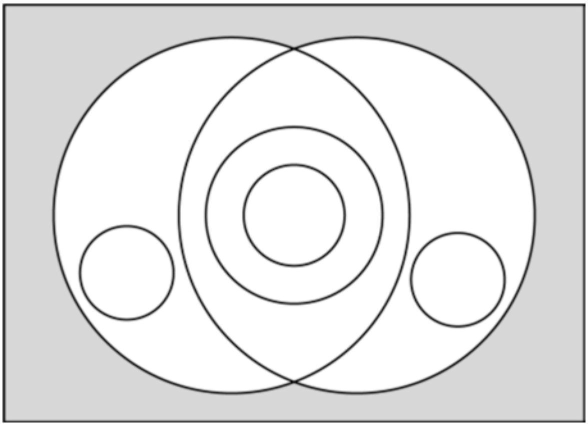


Fig. 2 Accidental learning: neither intended learning nor guided learning (Type 1)

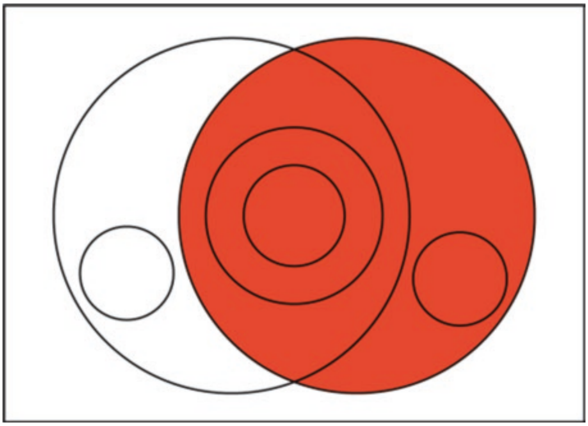


Fig. 3 Guided learning (Type 2)

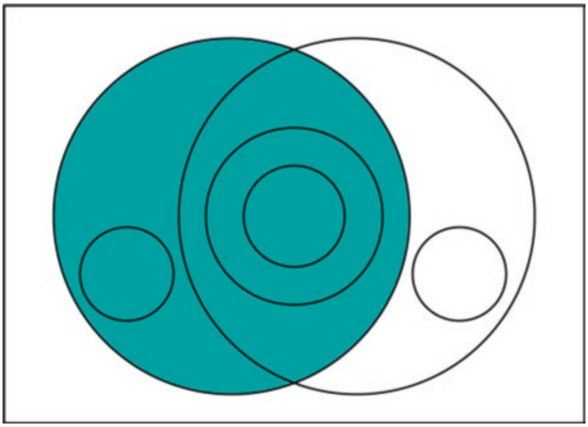


Fig. 4 Intended learning (Type 3)

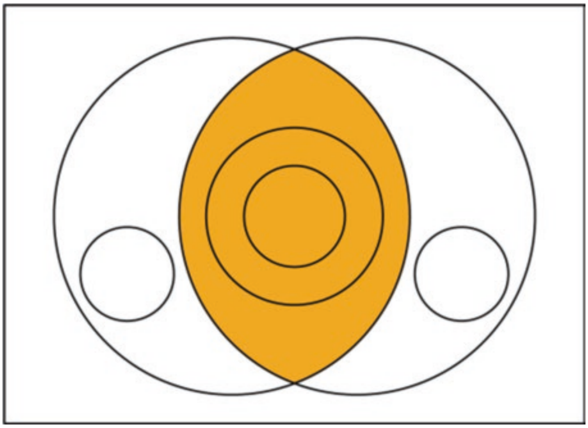


Fig. 5 Conducive learning (education): intended learning and guided learning (Type 4)

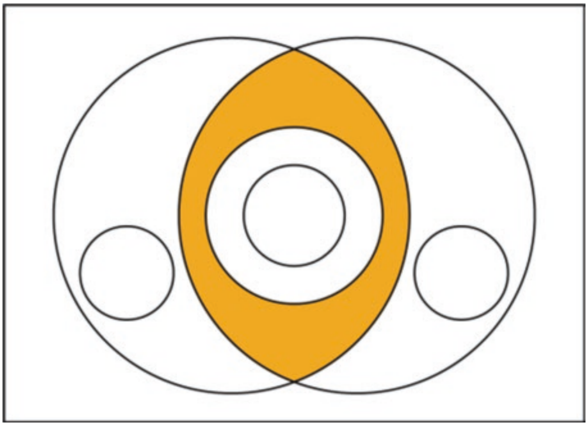


Fig. 6 Ineffective education: neither instrumentally good nor intrinsically good (Type 5)

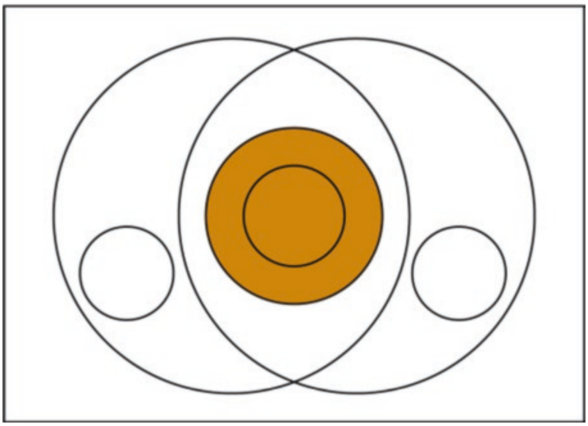


Fig. 7 Effective education: instrumentally good (Type 6)

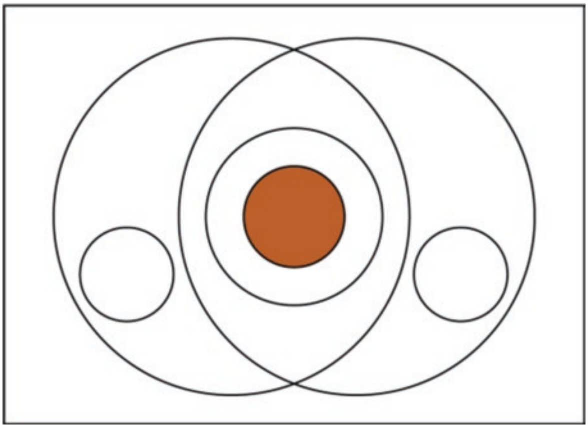


Fig. 8 Worthwhile education: instrumentally good and intrinsically good (Type 7)

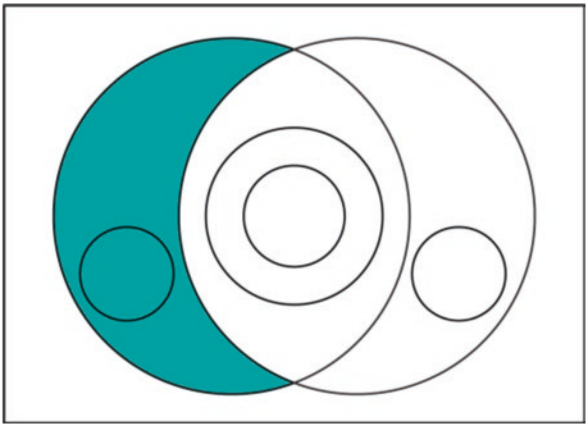


Fig. 9 Discovery learning: intended learning but not guided learning (Type 8)

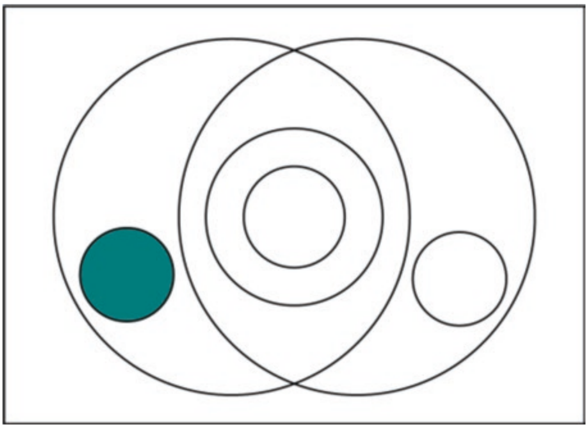


Fig. 10 Disciplined inquiry (research): discovery learning that is regulated by criteria (Type 9)

Fig. 11 Compelled learning: guided learning but not intended learning (Type 10)

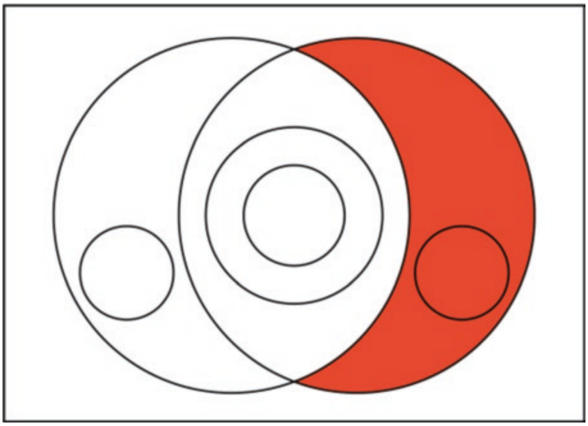


Fig. 12 Induced learning: guided learning but initially not intended learning (Type 11)

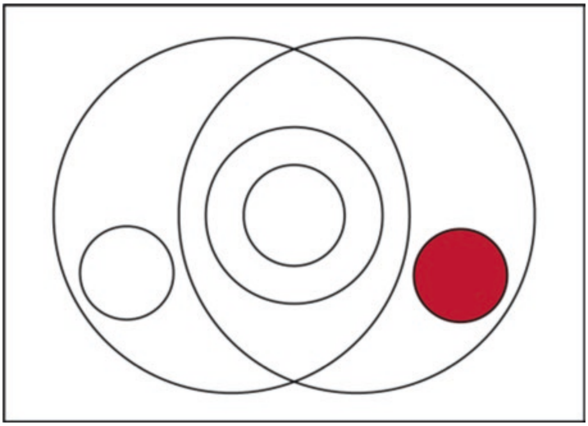
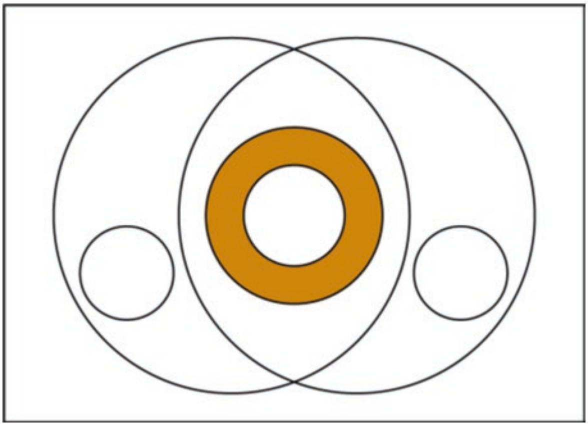


Fig. 13 Effective yet bad education: instrumentally good but not intrinsically good (Type 12)



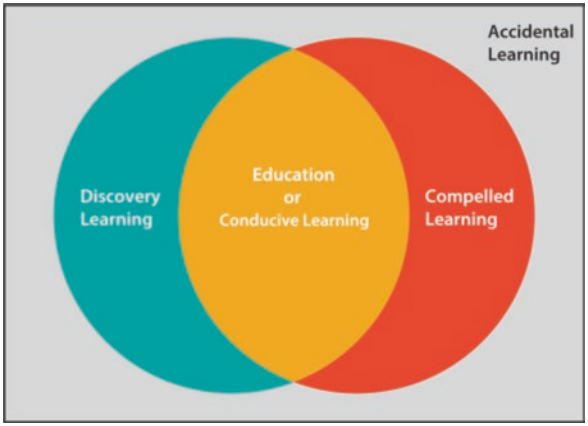


Fig. 14 All learning: accidental learning or discovery learning or conducive learning or compelled learning

teaching methods could be highly effective, where students attempt to learn, and they succeed; however, what is being learned is not worthwhile. This would be exemplified by students going to school, who try hard, and who score highly on standardized tests; but unfortunately, what they have learned lacks intrinsic value.

As another example, *compelled learning* is "a person's *learning* which is *guided* but not *intended*" (https://educology.iu.edu/compelledLearning.html). This would be exemplified by individuals who do not try to learn, while nonetheless are guided. That is, they might be going to school where they are being taught, but no *education* is occurring; and they are in fact not actual *students* because they do not intend to learn what is being taught. These situations contrast with *worthwhile education*, which is "*effective education* that is *intrinsically good*" (https://educology.iu.edu/worthwhileEducation.html).

Given these distinctions in *Educology*, one might ask: How much *worthwhile education* is occurring in American schools versus *compelled learning*, *ineffective education*, or *effective yet bad education*?

How Is Educational Theory Different from *Educology*?

Education provides *guided* and *intended learning* across various human disciplines. The result of *disciplined inquiry* about *education* is distinct from the process of *education* itself. If adequate, educational research should result in *knowledge* about *education*—that is, *Educology*.

In *Educology*, *theory* is defined as "intersubjective signs of universals about essential properties and their relations, yet to be warranted by disciplined inquiry" (https://educology.iu.edu/theory.html). Therefore, *educational theory* is intersubjective signs of universals about essential properties and their relations about *education*, yet to be warranted by *disciplined inquiry*. And *education* is defined as *conducive learning*—*learning* that is both *intended* and *guided*. See Figs. 5 and 10.

In *Educology*, *knowledge* is taken to be "recorded *signs* of *knowing*." Such records are intersubjective, that is, between persons, and they are preserved in some medium over a period of time. Steiner (1988) argues that

> First, *knowing* should be distinguished from *knowledge*. *Knowing* is a psychical state in which one has certitude about something and has a right to that certitude… *Knowledge*, however, is recorded *knowing*; it is the body of expressed certitudes. (p. 5, emphasis added)

Recorded *signs* of *knowing* can be preserved in a variety of media. At one time, cave paintings, stone and clay tablets, and papyrus were used. Nowadays, in addition to printed paper and books, we have video and audio recordings, photographs, animations, and computerized games and simulations. We also have electronic storage devices to store records such as hard drives, flash memory, and the "Cloud"—remote storage on devices which can be accessed over computer networks such as the Internet.

The record of *knowing* consists of *signs*. The *signs* are not the object of what is known, but rather the *signs* represent what is known. Charles Sanders Peirce spent much of his life attempting to develop a *theory* of *signs* (Short, 2007). Peirce's *theory*, which he never finished to his satisfaction, evolved over his lifetime. Peirce (1932) defined *sign* as follows:

> A *sign*, or *representamen*, is something which stands to somebody for something in some respect or capacity…every representamen being thus connected with three things, the ground, the object, and the interpretant (2:228)… The *Sign* can only represent the Object and tell about it. It cannot furnish acquaintance with or recognition of that Object; for that is what is meant in this volume by the Object of a *Sign*; namely, that with which it presupposes an acquaintance in order to convey some further information concerning it. (2:231)

Disciplined inquiry is *discovery learning* that is guided by criteria for conducting research to create *knowledge*. Thus, educational *theory* becomes *knowledge* of *education* (i.e., *Educology*) when it is verified through *disciplined inquiry* (Frick, 2019; Steiner, 1988). *Educology* is also different from the process of *education*, which is the object of educational research (*disciplined inquiry* about *education*).

As an example, I have developed the theory of *totally integrated education* (TIE). TIE theory builds on definitions of *learning* and *knowing* in *Educology* and further distinguishes among *learner cognition*, *conation*, and *emotion* (Frick, 2018). Nine kinds of *knowing* are defined in *Educology* (https://educology.iu.edu/knowing.html). These definitions of basic terms then permit definitions of new terms: *integrated learning* and *integrated knowing* (see https://educology.iu.edu/integratedLearning.html and https://educology.iu.edu/integratedKnowing.html).

I have recommended that empirical research studies be carried out based on designing different kinds of *learning environments* according to TIE theory. Learning achievement—particularly long-term achievement gains compared with short-term gains—can be investigated by manipulating components of TIE theory. For example, in typical classroom learning in elementary, secondary, and postsecondary schools, *knowing that* is disconnected from *knowing that one* and *knowing how*. TIE theory predicts that, under these conditions, *student mental structures* will be weaker, more disconnected, and more vulnerable to *forgetting*, especially if *intention* to *learn* and *learner emotions* are disconnected during learning activities.

On the other hand, what happens when *cognition*, *intention*, and *emotion* are *wholly connected* with *knowing that*, *knowing how*, and *knowing that one* (illustrated at https://educology.iu.edu/integratedKnowing.html)? These two kinds of contrasting systems could be empirically compared on a number of dimensions—student motivation and satisfaction, attitude towards learning, mastery of expected learning outcomes, teacher satisfaction, and so on.

TIE theory has further implications for schools without walls, that is, *education systems* which include local community and culture as integral parts of the *education system* as *content* for *learning*. This contrasts with exclusion of *content* about what happens outside classrooms in the local community. In other words, if *students* are *learning* in real-world *contexts* (i.e., literally through hands-on learning activities), would they be better able to connect *knowing that* and *knowing how* with authentic parts of their culture (with *knowing that one*)? After all, for tens of thousands of years, humankind did *learn* in real-world *contexts* prior to more recent attempts via formal schooling in the twentieth and twenty-first centuries where *students* have largely been sequestered inside buildings.

If predictions from TIE theory are warranted through *disciplined inquiry*, then those claims become part of *Educology*—*knowledge* of *education*. The value of new *theory* is to predict unexpected, nonobvious, unseen, and counterintuitive outcomes (Frick, 2018; Thompson, 2006).

Why Do We Need *Educology*? Why Should We Care?

Trial-and-Error Approaches to Improving Education Are Risky and Inefficient

Educators who have been around several decades have seen widely touted changes come and go. In the past four decades, for example, some of the innovations have been referred to as site-based management, constructivist classrooms, technology integration, school restructuring, systemic change, and reinventing schools.

Despite such rhetoric, changes that have occurred in US K-12 schools appear to be “tinkering around the edges.” In 2019, for example, there may be more use of computer tablets, Chromebooks, and Wi-Fi networks in schools, more standardized achievement testing, more accountability for *student learning* achievement, less state funding for public schools, more tax dollars going to private charter schools, and increased regulation of schools by state and federal governments.

But have any of these changes significantly improved K-12 *education*? While apparently well-intentioned state legislators and state departments of *education* are mandating changes in K-12 *education*, there are no guarantees of improving matters.

Worse, these changes may cause more harm than good. The stakes are very high. The consequences of mistakes can be devastating for our children and our future. The following questions have not been adequately addressed:

"Change what?"
"Change how?"
"How do you *know* the change is likely to work?"

We must *know* what to change in order to *know* how. Without *knowing* what to change, the "how" is irrelevant (Frick, Thompson, & Koh, 2006). We must *know* whether the change is likely to accomplish the goal and that the change will not have negative, unintended effects.

For example, attempts to hold *teachers* accountable for *student* achievement not under their control may drive the best *teachers* to leave the profession, due to frustration with such working conditions. It may also discourage potentially good *teachers* from entering the profession. Moreover, the best *students* might leave the public schools to attend private charter schools, if their parents can afford it. This would leave public schools in possibly worse straits, with the least capable *teachers* and lowest achieving *students* remaining, and less money from public tax dollars to support them. Then what?

Paradigm Change for Improving Education Requires Sound Knowledge

Some scholars argue that an entire paradigm change is needed in *education*. For example, Reigeluth and Karnopp (2013) have promoted a vision and strategies to get there. These include significant curriculum expansion, individualized *learner*-centered instruction, and attainment-based evaluation of *learning*—that contrasts with existing time- and age-based structures for moving *student* groups through lockstep grade levels. As another example, Duffy (2009) is promoting systemic change efforts.

But do we know how well such new paradigms will work? This does not mean that a new *education system* that is learner-centered and attainment-based is not worthwhile. Nor does it mean that changes to expand and revamp curriculum in school are not needed. It just means that we lack sound *knowledge* to predict outcomes of new designs of *education systems*.

Why Sound Knowledge of Education Is Needed

As an analogy, consider an old bridge that is failing—it is structurally weak and is impeding the flow of traffic. If the bridge is not fixed, it will collapse, and vehicles will plunge into the river. When engineers design a new bridge, they utilize adequate scientific *knowledge*. No one in modern times would consider designing a new bridge by trial and error. Nor would they let politicians try to do it.

Yet, in *education*, we are essentially proceeding by trial and error in attempts to improve *education*—whether tinkering around the edges or by creating new paradigms. We lack sound *knowledge* to make reasonable predictions whether or not the proposed remedies will fix the problems in *education* we face.

Disciplines Require Precise Language

In disciplines where *knowledge* has significantly advanced, there has been careful development of terminology so that researchers *know* what each other is actually talking about. For example, in physics, the concepts of atoms and molecules are clearly defined. Each atom has a particular combination of subatomic elements called electrons, protons, and zero or more neutrons. For example, in chemistry, a molecule of water is comprised of two hydrogen atoms and one oxygen atom. A hydrogen atom consists of one electron and one proton. A stable oxygen atom contains eight each of electrons, protons, and neutrons (see Properties of water, n.d.).

As another example, it was not long ago that the field of medicine was not a discipline. There was no medical science, as there now is. At one time, physicians would prescribe bloodletting to treat all kinds of disease, which turned out to be an ineffective practice and has been largely abandoned (Bloodletting, n.d.). Many people were harmed by such ignorance.

Medicine advanced, in part, because researchers in the field became more disciplined in their inquiry. Terms are now precisely defined in medicine. Osteoarthritis does not mean whatever people want it to mean. Osteoarthritis is the precisely described medical term for a particular disease. Researchers and practitioners in the field of medicine have agreed on what this term means. Thus, when treatments of this particular disease are investigated, competent medical professionals *know* what they are talking about.

The Need for Precise Language in Educology

In the field of *education*, such precise terminology has not been developed until now. Steiner (1977, 1986, 1988) has long argued that such terminology is sorely needed for the field to advance and has proposed the term *Educology* to mean "*knowledge* of *education*."

Basic terms of *Educology* have now been defined: *learning*, *knowing*, *signs*, *education system*, *teaching-studenting processes*, *teaching-studenting structures*, and many others. The definitions are available to all at the *Educology* Website at https://educology.iu.edu/glossary.html.

A standard vocabulary will lead to advances in *Educology* that, in turn, will help improve *education*—that is, develop *worthwhile education for everyone*.

Worthwhile education for everyone is needed to:

- Enhance the quality of life
- Reduce inequality
- Minimize suffering
- Maximize overall good (https://educology.iu.edu/we2.html)

How Do We Move *Educology* Forward? Next Steps?

During the Summer 2019 AECT Research Symposium, a number of participants indicated that, while they see the benefits of establishing *Educology* as a discipline, similar questions emerged from several different groups: How can we make this happen? What are practical next steps?

These are clearly important questions. Suggestions from symposium participants included the following: create a professional organization, possibly located in an Institute for *Educology* or a research center on a university campus; consider joining forces with other established groups such as the Glossary of Education Reform (https://www.edglossary.org/), the United Nations Educational, Scientific and Cultural Organization (UNESCO: https://en.unesco.org/), or the International Organization for Standardization (https://www.iso.org/home.html).

It may be further worthwhile to study established professional organizations and their history of development. For example, the American Medical Association (see https://en.wikipedia.org/wiki/American_Medical_Association) could potentially serve as a model. The AMA was formed in 1847 to improve public health, to advance competent research in medical science, and to establish medical education standards. Note that at that time, over 170 years ago, many "quack remedies" were being promoted to the American public which had no scientific evidence to support their effectiveness and safety, and, in fact, could be harmful or fatal—for example, the proverbial snake oil salesman.

In general, the problem is one of adoption of an innovation. In this case, the innovation is the *discipline of Educology*. Everett Rogers (2003) was a prominent researcher who identified critical stages through which diffusion and adoption of innovations typically progress. "Diffusion is the process in which an innovation is communicated through certain channels over time among members of the social system" (p. 5). According to Rogers, factors which influence the rate of adoption of an innovation include perceptions of its relative advantage, compatibility, complexity, trialability, and observability/visibility. These factors, in turn, affect the amount of time for the diffusion process to occur and indeed influence whether or not it is ultimately successful.

While the *Educology* Website is clearly a communication channel, more channels will be needed in the future. I created the current website as a starting point (https://educology.iu.edu), to serve largely as a centralized reference for terms and their definitions. The website is but a first step to increase awareness of *Educology*. What will stimulate interest and willingness to give *Educology* a try remains to be seen. The relative advantage of *Educology* should be demonstrable improvement in education itself that, in turn, clearly improves the quality of life in the social system. This is the daunting challenge. The length of time required to observe such impacts is likely to be decades, if not centuries. Others beyond myself will need to carry the torch.

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Multimodal Social Semiotics and Learning Design: In Search of Interdisciplinarity

Begüm Saçak

Without integrative disciplines of understanding, communication, and action, there is little hope of sensibly extending knowledge beyond the library or laboratory in order to serve the purpose of enriching human life.

Buchanan (1992, p. 6)

Introduction

The works of two scholars, Gunther Kress and Theo van Leeuwen, created the theory of multimodal social semiotics rooted deeply in the fields of linguistics and semiotics. The theory's far-reaching components, specifically regarding understanding and creating media, received attention from other disciplines. One such discipline is the field of learning, as an analysis of multimodality in a communication practice involves crucial questions such as "what modes have been used, and what learning is evident in each of the modes used" (Kress & Bezemer, 2015, p. 168). In this paper, multimodal social Semiotics theory informed by linguistics and semiotics will be introduced based on the work of Kress and the theory of multimodal social semiotics. In the rest of the paper, a preliminary suggestion of interdisciplinarity will be given based on the implications of how theory of multimodality can inform the field of learning design.

In memory of Gunther R. Kress (1940–2019)

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Background

Language is one of the most fundamental means of meaning-making for human beings. Multimodal social semiotics is rooted in linguistics (the study of language) as conversations and approaches in this discipline led to the conceptualization of Kress's theory. The field of linguistics was still blooming when Chomsky (1965) proposed his idea of universalism – a theory of language which will later gain worldwide recognition. Universalism is the idea that every human being is born with a language acquisition device (LAD) in their mind, which helps them acquire language at a very young age. The theory received some criticism from some scholars such as Piaget (Piattelli-Palmarini, 1980). One of the main criticisms of universalism was that the theory accounts little for the evolutionary processes and how LAD came into existence. Similarly, linguist and semiotician Gunther Kress criticized the theory, asserting that its asocial nature left nothing to society and human creativity (Hodge, 2013; Kress, 1998). In Kress's mind, language was much more than Chomsky's universalism – it should be less linear and reductive and more open to social and other dimensions (Hodge, 2013). In the 1990s, Kress and Theo van Leeuwen started talking about multimodality.

It is possible to trace back the origins of multimodal social semiotics to Halliday's fundamental theory of grammar. Halliday's theory of language and meaning diverged considerably from Chomsky, as the emphasis was on text, which is defined as a process of meaning-making in context (Halliday & Matthiessen, 2013), whereas Chomsky's theory of language is more concerned with innate linguistic competence. In his linguistic analysis, Halliday (1978) emphasized the generative power of "the social" in language, which addresses "the close fit between social organization, human action in social environments, and the meaning potential of linguistic forms and processes" (Kress, 2010, p. 60). Kress and later his colleagues used Halliday's theory of grammar as "a means to ground a social critique in a close attention to the grammar of language" (Iedema, 2003, p. 30).

Halliday (1978) developed *systemic functional grammar* – a tridimensional theory of meaning (Iedema, 2003). Unlike some other theoretical explanations of language, systemic functional grammar is about the specific functions – namely, the purposes of language use. Halliday's systemic functional grammar is about how speakers generate and communicate meanings through "the generalized metafunctions that relate language to the outside world where interactants and their social roles matter" (Haratyan, 2011, p. 260). The three main metafunctions are *ideational*, *interpersonal*, and *textual* aspects of meaning.

Halliday's work is important because it enabled the analysis of "language from a social semiotic point of view" by addressing the structures "above the sentence level" (Iedema, 2003). Kress's multimodal social Semiotics theory derives from Halliday's theory of language by asserting the idea that "language is social" (Jewitt, 2006, p. 3), and linguistic account of meaning is partial. Kress (2010) criticizes the European intellectual traditions, as they put a great emphasis on language in describing communication practices. Linguistic meaning has always been regarded as the guarantor of rationality and knowledge (Kress, 2010). However, an important question remains: Is language the most comprehensive means for communication?

Language constitutes an important part of human communication, but reducing communication to language is not enough to explain complex interaction patterns human beings use to communicate with each other. Communication is based on the meaning-making process in which different signs are used and interpreted in social interactions. The theory of multimodal social semiotics was born in an attempt to explain meaning-making practices through social actions and interactions (Kress, 1997, 2003; Kress & van Leeuwen, 1996, 2006). Though the Hallidayan approach to language also puts great emphasis on the social functions of language units and use, social semiotics is based on the idea that "representation and communication always draw on a multiplicity of modes, all of which contribute to meaning" (Bezemer & Jewitt, 2009, p. 183). Kress and van Leeuwen's theory of multimodal social semiotics was born as a result of the increasing reliance of nonlinguistic modalities (i.e., visual, sound, mimics, etc.) rather than linguistic ones in our daily communication practices. The shifting paradigm from "the idea of textuality" to the "post-semiotic discovery of picture" marked the beginning of a new era in the field of semiotics and paved the way for the creation of the multimodal social semiotic theory (Manghani, Piper, & Simons, 2006).

> In the term *Social Semiotic Multimodality* inheres a division of labour: "Social Semiotics" provides a full theory of meaning, while "multimodality" provides an account of the modes which are available for making meaning material in a particular community; it elucidates some of the major features of the different modes. Multimodality as such is not a theory; it marks out the field which is relevant for the investigation of meaning. It does, however, have one far-reaching theoretical effect: the claim that all modes, always in combination with other modes, are drawn into meaning-making, which means that the two linguistic modes of speech and writing are treated as two among all modal resources for making meaning. That makes the previously taken-for-granted centrality of speech and writing no longer tenable. If meaning is made in all modes, then the overall meaning of a "message" is the result of the combination of meanings provided by all modes in use in a "message." Each mode is seen to make a partial contribution to the overall meaning. That is as true for speech as for writing, as much as for image – still or moving – for gaze, gesture, for objects-as-modes, and so on. (Kress & Bezemer, 2015, p. 155)

In other words, multimodal communication has more expressive affordances than language (i.e., written and spoken language). Instead of linguistic units, a multimodal communication can include, but not be limited to, "image, writing, layout, music, gesture, speech, moving image, soundtrack, and 3D objects" (Kress, 2010, p. 80). In other words, rather than relying on abstraction, multimodal communication is defined by "materiality" (Kress, 2014a).

Multimodal Social Semiotics as a Notion of Learning

The use of multimodality as a means of learning is not new. From early print technologies to various forms of dynamic media, multimodality has had its place in the field of education. However, thanks to the emerging technologies, there are more images used in educational settings than before (Bezemer, Jewitt, Diamantopoulou, Kress, & Mavers, 2012), and educational technologies such as AR, VR, and other online tools that incorporate diverse media are increasingly used for learning purposes.

Such changes in the semiotic landscape received some criticism as increased use of modes other than the written and spoken forms were not seen as credible, or in other words, such developments threatened the traditional notion of "literacy" (Bezemer et al., 2012). One thing such criticism did not take into account is "the empowering potential of such changes by their offering new routes into existing curriculum topics" (Bezemer et al., 2012, p. 10). In other words, the social semiotics approach can help us understand how learning occurs through the use of various modes and also how the use of multimodality, in fact, could foster learning.

In Kress and Bezemer's explanation of multimodal social semiotics, the theory has different constituents, which have strong implications for learning (Kress & Bezemer, 2015). The word "multimodal" entails the use of modes for meaning-making. Each mode has a different contribution to the overall meaning, and all modes in combination in varying degrees create meaning of the intended message. This fact also has implications for speech and writing – two modes which have traditionally been regarded as central, though it might not be always the case anymore.

> The effects of these assumptions for theorizations of learning are profound. On the one hand, it means that we must attend to all signs in all modes which are present in and constitute "learning environments" – whether as designers of these or as those who engage with such environments. We must be aware of what each mode separately and all modes conjointly contribute to the meaning(s) of that environment. On the other hand, we must be aware that all signs in the modal complex act as – or can potentially be taken as – prompts for engagement. (Kress & Bezemer, 2015, p. 155)

Modes and their affordances are critical as they contribute to the creation of overall meaning, and in learning environments, not only the written text or speech but also other modes which together convey meaning are important as learners construct their knowledge based on an understanding of multimodal ensembles. Rather than abstraction, nontraditional multimodal ensembles are defined by "materiality" (Kress, 2014b). In other words, instead of relying on phonemes and morphemes, the meaning of modes other than written/spoken language is defined by concepts including, but not limited to, spacing, color, proximity, perspective, pitch (for sound), or haptics.

The nature of such materiality and the meanings are defined by what is "social" – in other words, the meanings we collectively attribute to the material world around us. Participants engage in the social world by interacting. Interaction always has semiotic implications as we communicate with others by relying on the semiotic and cultural resources.

> One criterial, defining feature of the social world is (inter)action. "Communication" is an instance of (inter)action par excellence. From a social semiotic perspective (inter)action/communication constitute semiotic work. Meaning arises in social-semiotic (inter)action: It is the result of semiotic work by social actors, acting with socially made cultural resources, to produce signs. Signs are the product of semiotic work. The sign is the unit in which meaning is made material and evident. In (Social) Semiotics, the process of learning is an instance of (inter)action, of communication, of semiotic work. Learning is both an instance and an outcome of (inter)action and/or engagement and sign-making. (Kress & Bezemer, 2015, p. 157)

The idea that learning is a semiotic process with its foundations on interaction and communication means that learning takes place in all social-cultural environments, including spaces of formal learning (Kress, 2019). There are a plethora of meaning-making practices and diversity of interaction, which means there are so many diverse ways to learn from and interact with each other. Instructors (or instructional designers) have now this crucial role of designing learning environments by using well-designed instructional prompts (Kress, 2019), and one of the main elements of such learning design would be creating interaction within a multimodal context in ways that would result in meaningful learning experiences.

Kress and Bezemer (2015) gave a nontraditional learning environment as an example for multimodal learning environments. In Fig. 1, surgical training scene in the operating theater located in the Science Museum in London was reenacted as a way to demonstrate different scientific scenery so that the audience can become

Fig. 1 Science Museum in London. (From "A Social Semiotic Multimodal Approach to Learning," by G. Kress and J. Bezemer in D. Scott and E. Hargraeves (Eds.), *The SAGE handbook of learning* (p. 63), 2015, London, England: SAGE. Copyright 2015 by SAGE. Adapted with permission)

more familiar with a particular scientific setting, and they could get a glimpse of a surgical procedure. The particular scene depicted in Fig. 1 is pretty different from a traditional instructional material (such as a textbook) as it is possible to see real figures of actors in the setting – the surgeons and the patients.

In the absence of written text, one's attention turns to other components of the learning environment. As we look much closer at this setting, it is possible to see the medical equipment used in the procedure, the materials used such as gowns, and a small screen in front of them showing the "laparoscopic" video footage from a simulated operation conducted and recorded earlier (Kress & Bezemer, 2015). This multimodal scenery consists of a lot of semiotic resources, as all the material objects and the actors within this setting constitute an instructional message. If we were to analyze the setting in Fig. 1 in detail from a multimodal social semiotic perspective (analysis of signs and their social use), it would be possible to account for the material objects, facial expressions, positioning of different elements/actors, and their contribution to meaning-making along with the social meaning that arise out of this particular multimodal ensemble.

Kress and Bezemer (2015) also highlighted how the audiences' faces reflected their interaction with this scene. Through their facial expressions, to some degree, it would be possible to see what captured their attention and how they paid attention to different material elements of this reenactment scene. What is intriguing is that though the multimodal ensemble, in other words, the whole scene was a single example of surgical training. The audience's attention was drawn to different elements, which imply "different transformations and transductions of what – from the design team's point of view was the 'one' sign complex" (Kress & Bezemer, 2015, p. 166). The authors later examined a blog post written by one of the visitors to better understand how the material elements demonstrated in the theater were transformed and integrated into new sign complexes by the learner. The blog post reflected how the material scenery translated into learning since the learner had the chance to analyze the learning environment from a nontraditional lens.

Given the multiplicity of modes and novel ways of representations, a certain content can be demonstrated to learners in ways that are more immersive, revealing, or multidimensional ways. What has been neglected before, different modes and what they entail for learning, could be harnessed and used for more immersive learning experiences.

Increasingly, new technologies are used to create such multimodal learning environments. Virtual reality (VR) technology is one of the ways to create immersive learning. A virtual reality game titled *Becoming Homeless: A Human Experience* was created by the Stanford VR Lab to explore how VR affects people. The game is about the actual experience of becoming homeless, and the game was created with visual and sound elements in VR platform for a better multimodal experience. The main goal of the game is to try to save one's home and belongings as the players walk in an imaginary homeless person's shoes. According to Stanford's Virtual Human Interaction webpage ("Becoming Homeless," 2017), the game was created so that the learners would learn that losing one's home due to one's own character and the choices one makes is indeed a misconception.

Similar to Fig. 1, in Fig. 2, the learning environment is quite different from what we would expect from a traditional learning environment. Learners are placed in a virtual reality environment, and they find themselves in a setting with a variety of objects to interact with. The objects – what they are and how they were distributed – along with the possible interactions within this constructed reality pave the way for new meanings to be made by the learners. By looking at the particular instance in Fig. 2, a learner would be able to see some signs of disorder and discomfort – an eviction notice, some papers where we can clearly see some sections have been crossed out, a trash can next to the desk, and a dirty dishes on the desk. The eviction notice on the table clearly indicates the reality, and the papers on the desk with strikethroughs imply that the main character or the player has already brainstormed about different options for figuring out a solution for the existing problems. The trash can next to the desk intensifies this implication as it might be possible to infer some options did not work out, or maybe some bills and final notices might have been tossed away. The presence of the plate and the empty cup also contribute to the creation of a sense of disorder and discomfort.

In Fig. 3, another scene from the game depicts an empty room and the furniture is missing. Interestingly, it is possible to see the shadows of the lost furniture as a reminder of what has been lost and what was there once in the past. Such feelings and sensations of loss are digitally replicated by the use of digital images, but what really makes the difference are the social signs and how these are interpreted by the learners. As in Fig. 1, both Fig. 2 and Fig. 3 reflect the intended message through a set of multimodal ensembles with almost no written text. A learner can decode and understand the social meanings, which are results of signs, how they are used together, and their positioning within a semiotic context.

Fig. 2 A screenshot from the game *Becoming Homeless* with a desk and various items. (From *Stanford Virtual Human Interaction Lab*, https://vhil.stanford.edu/becominghomeless/. Copyright 2017)

Fig. 3 A screenshot of an empty room of a house from the game *Becoming Homeless*. (From *Stanford Virtual Human Interaction Lab*, https://vhil.stanford.edu/becominghomeless/. Copyright 2017)

Becoming Homeless is an educational VR game which can be used for various educational purposes. Students can write reflections based on their experiences and what they have learned, participate in discussions, and even write a paper based on what they have learned. Through their reflection and understanding of the multimodal signs, the learners in fact participate in the meaning-making process as well, and they derive meaning from non-written modes.

Understanding how modes contribute to meaning-making and providing different means of interactions for learners can positively affect design of learning environments. The role of multimodal social semiotics as a theory is the analysis of multiple modes, their contribution to meaning, and a careful examination of how meaning arises through interaction and interpretation. A better understanding of modes' affordances and how they will be used can result in richer learning experiences.

The social and semiotic domains are constantly changing, and multimodal social semiotic approach could help us understand how learning occurs in multimodal environments. It is also possible to see how particular messages conveyed through modes and the way they are assembled and how they lead to transformation of individuals as learners interpret and understand the meaning of the modes within a particular learning context.

> Learning names both the process and the outcome of the transformative engagement by an individual with an aspect of the world – the "prompt" – which is the focus of her or his attention, with principles brought by her or him to that engagement. That engagement leads to a transformation of the individual's semiotic/conceptual/social resources and in the ceaseless transformation of these "inner" resources in social-semiotic action, there is a constant transformation of identity. (Kress, 2019, p. 27)

Conclusion and Implications for the Learning Design Field

Kress and van Leeuwen's comprehensive theory based on multimodal social semiotics (1996, 2006) and later works paved the way for a new understanding of meaning-making practices in media-rich environments. However, one important point is that social semiotics as a theory comes to life when it is applied to problems and instances in the real world, and it requires immersing oneself in semiotics concepts and methods as well as other fields (van Leeuwen, 2005). In this paper, it was shown that multimodal social semiotics can apply to any multimodal communication setting, and there have already been studies which used the approach as an analytic lens to better understand design choices and meaning-making through design.

Instructional design is a field where resources for learning and training are used for the best learning outcomes in a given context. Semiotic resources and modes are used extensively and inevitably in instructional design processes, and designing constitutes an important part of instructional design as a practice. A multimodal and interdisciplinary perspective on the use of these resources and their implications on learning design remains an area of research which has seldom been explored. Could it be possible that we might be missing a point by ignoring the design and inherent semiotic affordances of such design by putting a one-sided emphasis on the learning? This is an ironical question considering how learning itself is deeply rooted in the effective uses of semiotic resources, yet instructional design field lacks a thorough understanding of our design choices and their implications. Kress and his colleagues' framework could provide instructional designers a more holistic and nuanced way of approaching and selecting resources or modes for better educational outcomes.

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Wisdom and Power: Using Information Theory to Assess the Transactional Relationship Between the Learner and the Knowledge Provider

Robert Kenny and Glenda Gunter

Prologue

As humans, we must keep reminding ourselves as to what we "own" intellectually. We are in an age in which artificial intelligence (AI) appears to be fostering a decline in direct human-to-human communications and the interpersonal flow of information. We increasingly suffer from an inability to think critically about what is being communicated. We thoughtlessly accept it in deference to an unfounded and false perception of the media presented as impartial and trustworthy. To do so ignores the fact that, in the end, algorithms are human-based and not some Spock-like objective filter. It is imperative that we do not mindlessly accept the ever-increasing and ubiquitous array of so-called information that is presented daily, especially in the classroom. Learners can be especially at risk unless the actual communication transactions occurring in the learning cycle are assessed as they relate to transforming information into understanding. Anecdotally, the net effect of increasingly rapid flow, speed, and perceived omniscience of AI-based communications appears to be evident in students powering down and becoming less engaged. This is the antithesis of the goals of designed instruction. To counteract this phenomenon, educational administrators and faculty have introduced initiatives such as the "mindfulness" movement on psychology, student advising, and student success strategies. The knowledge acquisition process seems to have become situational.

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Almost all information coming into everyday use is "mediated" by some form of technology. For purposes of this writing, the authors utilize the terms "technology" and "media" interchangeably in recognition of the emerging digitization and convergence of all forms of communications in this century. Further, technology can serve as an incentive system and act as a vehicle to motivate individuals to seek information.

As many before have noted, information is not "knowledge" or "wisdom." Wisdom equates to understanding and is difficult to measure. The difference between knowing something and receiving the information upon which it is premised can be especially troublesome if that information is biased or unproven. The filtering process involved with discovering truth is essentially a human endeavor and cannot be replaced by the instrument or artifact that is delivering the intelligence artificially. The first line of interaction and filtering is whether the information being presented is actually accurate and new, not known previously, or incorrect. Many software and hardware providers would have us believe that AI has bridged the gap between the two and allows individuals to mindlessly accept that information, implying being informed is the same as being knowledgeable. The axiom "knowledge is power" may need to be changed to "wisdom is power," based on the premise that information and its resulting knowledge can become apocryphal if unchecked communications are transacted. When you separate real and unbiased information from wisdom, you lose accountability. To paraphrase George Gilder (2013), we must not sacrifice wisdom at the altar of ill-informed knowledge.

Gilder (2013) proposed that most learning occurs by recognizing the surprises introduced and discovered during communications. That recognition needs to take place implies that some form of critical analysis occurs. This process must be in the purview of humans and not of the artificial intelligence that introduced the information. The entrepreneurial/mindful educator is the one who creates or unveils surprises in the learning experience. Similarly, an experienced instructional designer is one who can wisely integrate these surprises into lessons. Instructional designers' heads and hands hold an astronomical amount of technical information, skills, intuitions, habits, and practical experiences that cannot be understood by anyone or anything limited in experience. Most of this understanding is structured through the transactions that occur between the learner and the one providing the knowledge, whether it is a person, place, or thing. It is with that goal that we suggest that there is a place for media ecology as an academic discipline within the instructional design domain.

Mediated interactions and how they shape the message, the user, and their interpretations should all inform an instructional designers' decisions being made about which media/technologies are chosen. They are best suited to the learning experience across the four relationships that exist in the learning cycle (Gunter, 2007). With this view, the purpose of media ecology is to support the outcomes of design thinking in instructional technology. Students of instructional design need to ask the questions that cause them to interpret these relationships through a different lens.

Transactional Learning Theory

Transactional learning theory proposes the relationship between individuals is synergistic, as both the sender and receiver each contribute to influence the understanding of content and context of a message. Transactional learning theory grew from Rosenblatt's (1968) examination of literary criticism in the teaching of literature as a social discourse. Rosenblatt suggested a reciprocal and mutually defined relationship exists between the reader and the literary text. He argued that the term "interaction" conjures a picture of separate objects encountering one another and, due to social influences, often remained essentially unchanged. This definition may be insufficient for literary criticism (Probst, 1984). However, as McLuhan (1964) often argued, it is also misleading for many forms of instructional communication—especially those that are mediated, due to the mutual shaping of the exchanges that occur between the learner and the knowledge provider.

Transactional communication is crucial in online learning since online learning must be created through various different and interdependent communications modes. These are processes helping to develop online connections between parties. The message and transactional communication relationships must be understood and considered to not only create connections but also develop a trust and balance between student-to-student as well as student-to-instructor.

One way to assess the value and impact of instructional message content is to view these interactions through an information theory lens. In this context, learning is defined as the comparison of what a person knew before the transmission/communication and what they know afterwards. Gilder (2013) and Mehlenbacher (2010) referred to awareness of this phenomenon as the "surprise" that occurs when the receiver of information discovers what he or she did not know prior to the informational exchange. While Gilder was ascribing these surprisal moments to economics, Mehlenbacher contends this phenomenon is easily translatable into various learning situations.

Gilder contends identifying the surprise is often attributed to the concept of entropy. In these contexts, entropy can be viewed in seemingly contradictory terms. In biophysics, for example, entropy is premised on the creation of the world as a random event which just as randomly may end. Others borrowed the term to describe file compression suggesting that there is a point at which the size of a file can only be reduced to a certain size before losing its interpretability (referred to as "lossless compression"). Both have in common the idea that one can view them as both having high and low values simultaneously. This apparent contradiction correlates to transactional learning in some ways. When viewing the transactions that occur between the learner and the knowledge provider both carry weight. This represents an individual being able to separate content or information that engenders the "surprise" from whatever else exists in the channel (i.e., the "noise"). Noise is that which can potentially hinder the ability to translate and make information valuable and convert it into knowledge and wisdom (Brown & Duguid, 2000). The degree of disorder or randomness in the system.

Assessing the transactional communication that occurs between learners and knowledge providers is to discover that which can interfere with arriving at the desired outcomes in the communication process. To this end, we concur with McLuhan (1964). The medium one uses to communicate a message influences how it is interpreted and comprehended. The value of investigating instructional transactions in this way increases the ability to successfully segregate out the noise/bias making the surprise or eureka moments more discernable and assessable. This process is considered by some to be at the heart of information literacy (ACRL Framework for Information Literacy for Higher Education, 2015).

Two Pivotal Instances in Learning

Learning can be described as being comprised of two distinct but seminal instances. The first relates to the initial communication when new information is introduced. The second occurs when previously known information is reintroduced with the goal of making it routine so that it can be enacted upon or reacted to automatically. This latter moment is sometimes referred to as naturalization or automaticity (Bargh, 1989). During routinization, the need or the desire for surprise is lessened which can actually interfere with one being able to discern what is new. In this case, the information is not surprisal in nature and may be, in fact, acceptable or desirable. On the other hand, if surprise is misused or inappropriately timed, it becomes a metaphor for the "noise" in the channel.

These ideas are premised on the assumption that robotic technology and associated algorithms can make the routinization process more automatic. While utilizing AI or robots with the naturalization or automaticity phase of learning may be a good thing, it is important to not mindlessly turn open the entire learning process to this bias or filtering.

AI's Role in the Learning Process

Artificial intelligence has recently become a major component of Alphabet's (i.e., Google's) long-range business plan, as led by Ray Kurzweil and others. Previous theorists and statisticians played a significant role in influencing Kurzweil's ideas on AI and singularity (Reedy & Galeon, 2017). Massively enhanced computing power can have seemingly endless capability for evaluation and production for any fixed text. This recalls statisticians Borel (1913) and Eddington (1927) in the early twentieth century creating the *Infinite Monkey Theorem* to illustrate the timescales that are implicit in statistical mechanics. Google has repeatedly demonstrated their willingness to follow and support this idea as noted in their business model (Cuofano, 2019).

The idea of near-infinite computing power has become the foundation to many assumptions about learning, assessment, and evaluation and how they may eventually be able to minimize or eliminate the need for human interaction and participation for including surprisal information in the instructional process. The intent is to take all randomness out of learning and making that process totally predictable. This view of learning serves for routinized learning situations and ties directly with potentially replacing teachers with machines. The assumption is if most or all learning can be routinized and made predictable, the need for human interactions in teaching and learning is lessened.

The premise behind promoting artificial intelligence (AI) initiatives in education and training is that a highly predictable and much needed communications channel is made available. Predictability and routinization are the purview of robots. In contrast, a human's role in this initial communications channel is to synthesize the newly communicated information and to learn how to separate out the "noise." Sometimes these two moments occur simultaneously. In these instances, AI's role is to process redundant and repeatable information in an amount and at a speed that it becomes "profitable" to the learning cycle by freeing up humans to decipher the surprisal moments and take action when new information is introduced.

What that means for the future of education is still unclear. It does cause one to pause and think about the ramifications of unthinkingly inserting teaching machines as the major knowledge providers in our society (Lombardi, 2016). Teaching and learning, as a whole, is about human learning. Humans make assumptions, synthesize and create the narrative during the learning cycle, and seek "surprise." To make the point about the richness of storying, anthropologist Gregory Bateson was asked if he thought artificial intelligence in computers was possible. He responded:

> "I don't know for sure, but if you ask a computer a simple 'yes' or 'no' answer and its response is 'that reminds me of a story', then it would be close." (cited in Favareau, 2010)

Bateson and Weizenbaum both noted the need for humans to decipher and synthesize surprises and to act on them (Dahlin, Chung, & Roulet, 2017).

The algorithms instructing AI programs or robots how to handle the routine and predictable have been, until now, the product of human intervention. This concept, too, is a part of the evolution of our theory of transactional learning.

Entrepreneurial Thinking, Knowledge, and the Experience Curve

Gilder alluded to the danger of completely succumbing to the unfettered use of AI in the knowledge acquisition process. Artificial intelligence can be seen to rely entirely on the algorithms programmed by humans. Even with building robots and other forms of AI, the role of humans is significant and some form of filtering or bias is always present. For the classroom, we have yet again arrived at a foundational need to incorporate information literacy in our instructional technology programs.

In commerce, the key to measuring the success or prowess of a business is gauging its "entrepreneurial" knowledge—its intellectual property as protected by patents and copyrights, but also its deep knowledge about its customers and procedures, developed high entropic moments, that is, surprisal knowledge (Gilder 2013). In education, we can borrow from this concept to assess learning prowess as measured by gains and the extent to which they are maintained, where increasing one's knowledge is the goal as well as through surprisal moments. The authors refer to these high entropic moments as reaching "intellectual entropy." By understanding the extent to which information presented in the classroom is considered low entropic activity, instructional designers can also recognize the number and placement of more complex teachable moments.

We contend the value/prowess of a classroom experience correlates directly with the amount of surprisal knowledge that is gained. It is as the job of instructional designers to recognize the problem of too much noise in the instructional channel and the negative effect on absorption and synthetization. It is also useful to recognize the transactional relationship between the learner and the knowledge provider, especially when those transactions are mediated by technology, as asserted by McLuhan (1964) and others.

Borrowing from economics, the experience curve axiom holds that the efficiency of any experience increases by 20–30 percent with every doubling of information (Gilder, 2013). In the learning experience, however, the opposite of this is true due to limits on cognitive load. What can be absorbed or synthesized by individuals *decreases* by about 70–80 percent with every doubling of information. It is common knowledge that information overload is an everyday experience. Parallel to Moore's law, the body of knowledge is said to be doubling every 18 months, and ever-increasing content being presented in the classroom. In many cases, the learning experiences that are being provided are merely those in which the content is presented in a manner to assist with simply covering the standards with little focus placed on actual mastery (Junkin, 2019).

In spite of the danger of overdependence, Artificial Intelligence can play an important role in helping where routinization is the goal. AI can be an effective learning provider where maintenance of knowledge is needed by becoming the primary learning source. This will allow human teachers to concentrate on discovering and synthesizing these surprisal moments.

The goal of splitting the roles between machines and humans as knowledge providers is to ensure that the former continuously examines the value of the various instructional transactions that occur. As long as humans are involved in processing and making judgments about information, Kurzweil notwithstanding, educators need to recognize that pressures to embed AI into our lives will not lessen but will become even more prevalent. The danger is that artificial intelligence may be putting us to sleep and disincentivizing us to remain a part of the information/learning process.

Mediated Messages Are at the Heart of Media Ecology in Instructional Design

There are succinct, implied connections between mediated communications and their effect on instructional design. Mediated interactions and how they shape the message, the user, and their interpretations all have a place in decisions that are made about which media/technologies are best suited to the transactional learning experiences. Exploring the characteristics of media is one way to assist with synthesis and attaining wisdom, helping to segregate "noise" from "surprise." George Gilder (2013) suggests that information itself does not inherit/acquire characteristics that interfere with its interpretation. It is the characteristic of the communication channel (i.e., the medium) that creates this conflation. In short, it is the environment in which information is distributed/channeled that affects the levels of noise. It is the role of instructional designers to disaggregate the two. It is also the role of teaching media ecology in an instructional design program.

While it was Neil Postman (1970) who actually coined the term "media ecology," Marshall McLuhan (1964) first suggested the concept of media ecology (without actually naming it) and how media shape the interpretation of the message. If one agrees that humans need to make choices as to how to remove confounds and to identify the surprisal moments, then, perhaps, McLuhan was correct and the concept of media ecology can be applied to instructional design.

Media ecology is the study of mediated transactions among people, their messages, and their messages systems as well as "technology" according to its broadest definition. In an instructional design curriculum, we study how media/technology can affect human perception, feelings, understanding, and value as it relates to the learning environment. In the communication environment, it involves viewing the transactions that occur between individuals and reality. Those transactions involve content generally occurring between the following (with their correlation to instructional design in each parentheses):

- One person and another (i.e., learner to learner, or learner and knowledge provider)
- Individuals and groups (the individual learners and other groups in the class)
- Groups and culture (classes or groups and the content that is situated)

We seek to extend this simple definition by including the modifying role played by the media and technology. The concept of media ecology as an academic discipline, especially in instructional technology curriculum, is still in its infancy. In fact, it is difficult to identify more than a handful of academic institutions that include media ecology anywhere in its curriculum. One mission of instructional design is to remove the issues with interpretation and wrong inferences.

For humans, all communications are transacted using some form of medium, whether it is text, video, audio, interactive systems, or a combination. The fact that a medium lives in a digital or an analog world is only relevant as to the particular kind of noise/interference that modality brings to the table.

Epilogue: Transactional Theory and Cognitive Research

An ongoing debate continues among researchers about the advantages and disadvantages of various cognition-based methodologies used to inform the design of instruction. On one hand, a main critique of cognitive research is that it fails to account for the social and cultural dimensions that tend to mediate learning (Östman & Öhman, 2010). On the other, sociocultural research is often critiqued because it tends to overlook the individual dimensions of learning and that those individual differences can disappear due to an overreliance on social interactions and biases.

The central effort, then, is to investigate and assess individual differences through a sociocultural lens and the four relationships that exist in the learning cycle: teacher-student, student-student, student-content, and student-technology. Reconsidering this requires an inquiry of methodological approaches to instruction that provides the requisite knowledge about how intrapersonal, interpersonal, and cultural dimensions influence and interact in the transactions that occur during the learning process with the understanding that those interactions may also be conflated due to their being mediated.

In its future research, the authors plan to further examine and demonstrate the impact of a well-defined approach to media ecology and its role in instructional design training programs.

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The Importance of Interest Development Across STEM Learning Environments

Bruce DuBoff

Introduction

What is interest? How is interest utilized, nurtured, and promoted in the STEM (science, technology, engineering, mathematics) classroom? How is interest related to STEM learning outcomes (Krapp, 2005)? New interests are possible at any time during any stage of a person's life (Renninger & Hidi, 2016), but the flipside of that is students can also lose interests at any time. This chapter will explore the nature of interest and learning, especially in the STEM classroom. Pedagogical recommendations are offered to educators and instructional designers based on viewing learning through the lens of interest development.

What Is Interest?

Interest drives our vocations and avocations. It influences what we do and enjoy at home, at school, at work, and at play. Renninger and Hidi (2016) define interest as the state in which, when people interact with an activity, they ". . . voluntarily engage in thinking about it, happily prioritize the problems that arise . . . and are willing to persevere to address them" (p. 1). People are hardwired for interest, and that tendency does not change throughout their lives (Renninger & Hidi, 2016); interest has a physiological basis (Renninger & Hidi, 2019). Interest has two components. The first refers to a person's psychological state while he or she is engaging with content, while the second is connected to a more long-standing affective and cognitive desire to reengage with the same content over time (Krapp, Hidi, & Renninger, 1992; Renninger & Hidi, 2016). The first type of interest originates from

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Table 1 Renninger and Hidi's (2016) four phases of interest development

	Less-developed (earlier)		More-developed (later)	
	Phase I: triggered situational interest	Phase 2: maintained situational interest	Phase 3: emerging individual interest	Phase 4: well-developed individual interest
Definition	• Psychological state resulting from short-term changes in cognitive and affective processing associated with a particular class of content	• Psychological state that involves focused attention to a particular class of content that reoccurs and/or persists over time	• Psychological state and the beginning of relatively enduring predisposition to seek reengagement with a particular class of content over time	• Psychological state and a relatively enduring predisposition to reengage a particular class of content over time
Characteristics	• Attends to content, if only fleetingly	• Reengages content that previously triggered attention	• Is likely to independently reengage content	• Independently reengages content
	• May or may not be reflectively aware of the experience	• Is developing knowledge of the content	• Has stored knowledge and stored value	• Has stored knowledge and value
	• May need support to engage from others and through instructional design	• Is developing a sense of the content's value	• Is reflective about the content	• Is reflective about the content
	• May experience either positive or negative feelings	• Is likely to be supported by others to find connections to content based on existing skills, knowledge, and/or prior experience	• Is focused on their own questions	• Is likely to recognize others' contributions to the discipline
		• Is likely to have positive feelings	• Has positive feelings	• Self-regulates easily to reframe questions and seek answers
				• Appreciates and may actively seek feedback
				• Can persevere through frustration and challenge in order to meet goals
				• Has positive feelings

outside of the individual and is called *extrinsic* or *situational interest*, while the second type, *intrinsic* or *individual interest*, originates within the individual. For example, Person X has recently become engaged with zines because he thinks they are cool (*situational interest*, triggered by context-rich zines and/or sharing and encouragement from friends), while Person Y is an avid collector who spends much of her free time reading and trading zines (*individual interest*, triggered by her frequent previous engagement and long-standing, context-rich relationship with zines and their communities); both people are interested in zines, but Person Y expresses a deeper, richer, and longer-lasting level of interest than Person X. Those levels are further defined in the *Four Phases of Interest Development* (Hidi & Renninger, 2006) (see above).

Empirical research on interest triggers has mainly consisted of experiments using specific novelties or challenges (Renninger & Bachrach, 2015). These triggers are teacher-presented, text-based, or activity-based using media or other learning resources (Rotgans & Schmidt, 2017). Triggers appealing to the natural tendencies of students and empowering them to internalize new objects, concepts, or ideas and then personalize them to make them more authentic are especially effective (Arnone & Reynolds, 2009; Durik & Harackiewicz, 2007). In the early stages of interest, perhaps for Person X, learners may not even know that their interest has been triggered; the power of interest is manifested when behavior changes based on the interest (Renninger & Bachrach, 2015). However, triggered situational interest can also be fleeting (Renninger & Riley, 2013; Renninger & Hidi, 2016); a volcano eruption, author visit, or worm dissection can be exciting today but forgotten tomorrow (Crouch et al., 2018). Additionally, seductive details, distracting information, and/or events that deter learning (Garner et al., 1992; Wade, 1992; Wang & Adesope, 2016) always seem to be ready to steal learners' attention with misreadings, ancillary facts, too much focus on graphics in a text or documentary, or even changeable weather.

In deeper interest levels, learners provide their own triggers (Renninger & Bachrach, 2015; Renninger & Hidi, 2016); they persevere with the task and even see themselves performing the task as part of their career (Renninger & Riley, 2013). However, at lower levels of situational interest, engagement and involvement may be fleeting without personal connection and perceived value, often manifested as "interestingness" (Hidi & Anderson, 1992; Patall, 2013). Although people tend to have four or five well-developed interests, there is always room for shifting and changing; focus on interests changes regularly (Renninger & Bachrach, 2015; Renninger & Hidi, 2016; Renninger & Riley, 2013). Engagement is an element of interest, but they are not interchangeable. One can be engaged but not interested, but one cannot be interested without being engaged (Renninger & Bachrach, 2015). Engagement in this respect can be seen as some level of involvement in an activity, a prerequisite for interest, but that is in this educational context only; the field of engagement research is not addressed here.

Interest can represent both a psychological state experienced in a particular moment situationally and an enduring predisposition to reengage with an object or concept/topic over time (Harackiewicz, Smith, & Priniski, 2016). The state of being interested is experienced as flow (Csikszentmihalyi, 1990; Renninger & Hidi, 2016), and if maintained, interest leads to enhanced academic performance or possibly to enhanced performance across many measures. Interest must be consistently nurtured to be retained, and students in different stages of interest development along the *four phases of interest development* model require different types of interventions, featuring personalization and authenticity whenever possible. Harackiewicz, et al. (2016) offer three dimensions of personalization:

> Depth—quality of the personal connections to learner's interests; authenticity of uses of popular and personal topics.
>
> Grain size—size of the reference group; is it individualized instruction for an individualized education plan (one student or a couple of students), or is it the type of individualized instruction a teacher would offer in a certain situation (many students)?
>
> Ownership—the degree of autonomy (á la *self-determination theory* (Ryan & Deci, 2017)) in generating the personalization. As expected, the more students self-determine, the deeper their connection gets to the content, and, it is hoped, the higher they rise in the *four phases of interest development*.

Interest development is a rich field that has shifted considerably since the publication of the *Four Phases of Interest Development* (Hidi & Renninger, 2006). However, the opportunity to be interested in STEM is not available to all students.

Socioeconomic Factors in Interest Development

Developed interest costs time and money, creating a potential disparity in STEM literacy (Aschbacher, Ing, & Tsai, 2014; Falk & Dierking, 2016). Many underserved populations did not and still do not have the chance to go to science museums, collect fossils, learn about surgical procedures, attend space or coding camp, go to field sites to develop scientific literacy, or use the Internet outside of school to go on virtual tours and watch STEM-related videos (Falk & Dierking, 2016; St. Jean et al., 2015). This can occur due to socioeconomic and personal factors such as single-parent families, lack of transportation, and lack of STEM-related career models in their lives (Falk & Dierking, 2016); many disadvantaged youths do not have access to some of the bridging activities between school and the outside world necessary to build scientific literacy and are therefore greatly in need of STEM subjects and experiences (Ahn et al., 2018). Many students are not able to stay after school or arrive before school due to family obligations. At-risk groups like girls of color and youth in lower-income families are ". . . far less likely than their more affluent peers to have access to, or to participate in, out-of-school science enrichment offerings, placing them at an educational and long-term economic disadvantage" (Brown & Rubinson, 2017, p. 6-7). It is society's responsibility (that falls upon STEM teachers) to ensure that all students have the opportunity to like, and engage in, STEM activities.

Understanding how and why students become interested in STEM subjects can generate improved strategies to ensure students are more prepared for, and self-interested in, pursuing STEM careers, which is not only necessary (Aschbacher, Ing, & Tsai, 2014; Falk & Dierking, 2016) but also just and fair to all students and citizens. Interest development has been linked in past work to digital literacy and STEM educational pathways; e.g., in the work of Reynolds' exploration in a 2-year-long after school computer club (Reynolds, 2008); the work of Shumei Zhang and Callahan (2014) using science fiction prototyping, through which students can create a relevant and authentic STEM-based item, real or imagined; and Ito's (2010) research that resulted in the connected learning and HOMAGO models. However, digital inequality, whether it is derived from socioeconomic, gender-based, or racially-based policies or beliefs, is a reality that must be addressed and corrected (Cooke, 2017; Riegle-Crumb, Moore, & Ramos-Wada, 2011).

Literacy, engagement, and ultimately interest and involvement in STEM-related professions are especially important in an increasingly complex world. Public science literacy development and advancement are related to interest development (Aschbacher, Ing, & Tsai, 2014), and STEM skills are vital to a competitive, dynamic, and competent workforce ready to face twenty-first-century technological and societal challenges (Isabelle & Zinn, 2017; Shumei Zhang & Callaghan, 2014; Krapp & Prenzel, 2011). Shortages in STEM fields are present and potentially growing, making it even more urgent to encourage young people to pursue STEM-related interests and careers (Rosenzweig & Wigfield, 2016); the world's future depends upon it, especially as it faces increasing pressure from climate change and its associated global crises and adaptations (Newell & Paterson, 2010). An examination of the theories that contribute to a complete understanding of interest development is useful in fleshing out best practices for instructional design and implementation.

Self-Determination, Achievement Goal, and Content-Specific Theories

Students will develop interest in ideas and activities because they think it is the right thing to do and/or because it is the desirable thing to do; the latter is more likely to lead to prolonged interest (Renninger & Hidi, 2016). However, prolonged interest needs access to feed it. An important part of this process is the blend of *autonomy*, *competence*, and *relatedness* connected with task satisfaction and dissatisfaction, described well by *self-determination theory* (SDT) (Ryan & Deci, 2017).

Autonomy is the state in which one feels volitional, congruent, integrated, and self-endorsed, in tune with one's authentic interests and values. The opposite is control, required to perform tasks and activities of less intrinsic interest (Ryan & Deci, 2017). Autonomy is much like well-developed individual interest (Renninger & Hidi, 2016), the highest level of the *four phases of interest development* model, in which students willingly and eagerly engage with material because they have chosen it (or assisted in the choice) and deem it useful and value-laden. The opposite of autonomy, *control*, is more like mandatory performance goal achievement, done by necessity and inciting potential performance-avoidance tendencies (Senko, 2016). Autonomy is based on intrinsic motivation like personal interests and exciting activities, while control is based on extrinsic motivation like success in corporate-style assessments and receiving praise or rewards for performing tasks in specific, predetermined ways with little or no personal input. *Competence* is the basic need to feel mastery, operating in harmony, effectively within one's environment (Ryan & Deci, 2017). It is readily thwarted with difficult challenges, pervasive negative feedback, and personal criticism and social comparison. Amotivation can be a symptom of a lack of perceived competence, either because a person feels unfit and unable to perform the task, the person is simply unmotivated and uninterested in performing the task, or the person is defiant or resistant to the activity, usually as a result of lack of autonomy. *Relatedness* is socially connectedness, belonging, and homonymy (Ryan & Deci, 2017). According to SDT, people naturally tend to internalize the values and goals of those people, groups, and entities, with which they want to be associated. The more a student attempts to act and think like a student, the more that studiousness will define that person's motivations and goals (Ryan & Deci, 2017).

Achievement goal theory (AGT) is also another useful tool that sheds light on interest development by contrasting mastery and performance goals (Senko, 2016). Students encounter triggers and interest with one of two strategies: performance approach (trying to outperform and show competence) or performance avoidance (striving to keep up with the class and not appear incompetent) (Dweck et al., 1986; Elliot, Church, & Geen, 1997). Mastery in this model operates much like *individual interest* in that the desire for success exceeds simple assessment and includes satisfaction, mastery, value, relevance, etc., while performance operates more like *situational interest* in that it is based upon environmental factors (triggers, interestingness) more than upon previous contexts and engagements. There is no logical avoidance component to mastery, since mastery accompanies self-generated interest and self-efficacy based upon that interest, two elements antithetical to avoidance. It is easy, therefore, to conclude that individual interest is "better" than situational interest, but the issue is far more complex than that. Individual interest is a function of autonomy, while situational interest is a function of control; both can promote learning based on the situation, and performance goals can be more effective in the classroom than mastery (Senko, 2016). Since students can have only a few individual interests at any given time, choosing interventions for both triggering situational interest and deeper engagement for activating individual interest is a balanced approach to this question.

Considering what prompts people to become scientists or to pursue scientific interests, Krapp and Prenzel (2011) ask whether interest is the motivation that encourages students to choose or reject scientific careers and activities. To Krapp and Prenzel, interest is always content specific; one is interested in something, concept, goal, vocation, or spouse; one cannot merely be interested. The idea that interests arise from interactions with social and institutional settings is called person-object theory of interest. Objects can be anything. Attitude and interest are not necessarily the same; one can have a negative attitude about sports but still have an interest in wanting the home team to win the championship because social factors based on region become involved. Also, interest and enjoyment can be related but they are separate emotions.

Theories like SDT, AGT, and content-specific interest are all patches in the interest quilt, adding richness to the lens through which interest is viewed. Rather than explaining interest development, they describe the cognitive and affective elements that comprise the environments in which interest can develop. As students approach the Vygotskian zone of proximal interest development, the space between what they are capable of developing interest in on their own and what they can accomplish with assistance (Ash, 2004; Schrader, 2015), they are then able to learn when collaborating with fellow students and/or instructors. Therefore, the process of learning should promote or lead to self-efficacy, in this case expertise.

Interest, Identity, and Expertise

Identity construction is crucial to engagement of interest. As students gather and process experiences, informal (non-school related) elements become increasingly important. Perhaps students should be afforded more opportunities to visit science-related sites, in-person, online, or both, during school hours (Subramaniam et al., 2012). As participants become more involved in an activity or organization such as a coding club or a conservation team, they move toward the center of that activity and assume more ownership and responsibility in the organization and the activity (Lave & Wenger, 1991). Educators may be partially responsible for not engaging students enough with real-life experiences communicated in a style that both students and educators can relate to (Pauw et al., 2015). Creating artifacts with personal significance is one of the best ways to introduce this; it creates a socially constructed creation space that drives scaffolding and learning (Kuhlthau, 1991, Reiser & Tabak, 2014). However, even if students build more content-related context and experience, they still need impetus to make connections to previous funds of knowledge which are not always activated.

Many learners have the skills to make meaningful connections but choose not to. Social media platforms are a bridge to such connections, and online groups should be organized around learning to enhance the possibility of critical connections (Mills et al., 2018). Social media can help students further craft their identities as future engaged citizens by discussing and sharing their experiences, affirming their choices with their peers (Subramaniam et al., 2012). Achieving these goals takes dedication by both students and staff, and it helps both if they like the material and, equally importantly, if staff stay current in their fields (Mills et al., 2018).

Context increases and more understanding becomes possible as expertise is built in a subject area. Background knowledge of content influences meaning construction through intertextuality, enabling students to more easily recognize similar topics, genres, and text features (Leinhardt & Young, 1996). Laypeople generally trust experts who are presented as such if they can establish a consensus concerning the data. Students are eager to seek and accept expert information, hence their willingness to consider the information in Google Answers boxes as factual with little or no vetting (Miklosík & Dano, 2016). Students are much more inclined to achieve expert acceptance if they can connect personally to it, since they are already socially instructed to accept that speakers talk about what they know, and laypeople tend to accept expert consensus as factual or at least sensible (Goldman, 2001). Therefore, expertise plays a crucial role in motivation and identity construction, since people identify with what they know and believe.

Students building expertise in a subject area, expanding context and deepening associations with specific disciplines like computing and engineering, and becoming experts in an area are key to building STEM interest and involvement (Pinkard et al., 2017; Van Horne & Bell, 2017). Additionally, there are specific storylines or narratives that are prevalent within societies, and they can be utilized for learning new subjects (Pinkard et al., 2017). STEM education can not only enhance involvement and interest, but it can also build context as it connects to already-existing narratives with which many students are familiar and comfortable. This approach is ideal for at-risk students who may not have as many inherent potential entry points as other students with stronger support systems outside of the classroom; for example, narratives can spark interest in STEM learning activities for middle school girls (Pinkard et al., 2017), a population long-neglected in STEM fields. Libraries can play a key role in this process by offering high-low, STEM graphic novels; many new series can appeal to students from almost any grade (Kimmel, 2013), an ideal example of building scientific literacy through interest. Two other media through which young people can empower themselves and demand a voice in the STEM world are zines and fan fiction. Zines, online, and/or print topical documents created outside of the traditional publishing world "represent the oppressed narratives that dominant informational sources sometimes willfully ignore" (Stahura, 2017, p. 177). Although some of them may represent hate and bigotry, the platform they provide for all people considered "the other" is palpable. Fan fiction heightens the narrative experience, often with attractive multimedia tools (Gretter, Yadav, & Gleason, 2017). It enables an additional level of context that fans of any particular universe, such as *The Hunger Games* (Collins, 2008) or Sherlock Holmes mysteries, can share, debate, and enjoy. Fan fiction adds an additional layer to alternate universes. Is Buffy the Vampire Slayer (Stuller, 2013) gay? Is Mr. Darcy (Austen & Rogers, 2006) a secret, anonymous abolitionist? How do Wookies use the bathroom? Like uchronic literature, the what ifs of history (e.g., *The Man in the High Castle*, Dick, 1962, in which the world is shifted into an alternate reality in which the Allies lose World War II), fan fiction gets to explore the forbidden, unexplorable, secret nooks and private desires of already existing characters. Sometimes, fictional constructs matter more than orthodox interpretation (Gretter, Yadav, & Gleason, 2017). Unfortunately, although students generally enjoy working with them more than traditional research sources, faculty are hesitant to allow the use of zines and fan fiction due to their lack of formal vetting (Stahura, 2017). They are another

Wikipedia to be feared by the old guard as the end of legitimate research, not authentic, vital, urgent information sources that can stimulate interest among middle schoolers. A sad irony is that Wikipedia has the same STEM gender gap as other media (Eckert, Metzer-Riftkin, & Nurmis, 2018). Instructors are wise to consider that Internet databases or trusted websites do not comprise the sum of valid student research opportunities; this is the same reductionist approach that prevents authenticity in research projects and encourages students to "get projects over with" instead of engaging in them and making them relevant and value-laden.

Personal agency is critical for students, and hopefulness and pride result from its successful implementation (Ely, Ainley, & Pearce, 2013). The range of positive feelings associated with interest offers no surprises or unexpected results; kids are more likely to respond with positive affect concerning the stuff they like, and they are more likely to respond with negative affect concerning the stuff they do not like. Offering pleasing content like graphic novels that also teach is one pedagogical bridge to interest generation.

Pedagogy and Interest

In her landmark study "The Case for Motivated Reasoning," Kunda (1990) writes that "The motivated reasoning phenomena under review fall into two major categories: those in which the motive is to arrive at an *accurate* conclusion, whatever it may be, and those in which the motive is to arrive at a *particular, directional* conclusion" (p. 480). This is based upon Kunda's distinction between *accuracy-driven reasoning*, in which subjects tend to ". . . expend more cognitive effort on issue-related reasoning, attend to relevant information more carefully, and process it more deeply, often using more complex rules" (p. 481), and *directional goal reasoning*, in which subjects ". . . attempt to be rational and to construct a justification of their desired conclusion that would persuade a dispassionate observer" (p. 482). Students do not merely choose between mastery and achievement goals when approaching academic achievement; there is a rich canvas of choices and contexts available to draw upon. This has profound implications for learning, since students must be convinced that either a subject and its associated activities and involvements should be engaged because it is socially appropriate and acceptable based on established standards or because involvement is personally desirable due to a variety of social and inter-generalizable, contextual factors. Walsh and Tsurusaki (2017) note that "Learners engage with social and material entities that mediate development and the transfer of knowledge, practices, and identities across an ecosystem and through time . . . forging connections between settings" (p. 6). It is those connections that drive engagement and interests and potentially learning. One of the goals of using Science Fiction (SF) to stimulate STEM interest and involvement is to capitalize upon and expand student contexts and interests, incorporating the elements of SF that are most appealing to the students, and to make it normal and appropriate to envision working with future technology by reading and practicing: "Learners' experiences within a particular environment are shaped by both their prior participation in particular communities as well as the structures, supports, norms, and expectations of the current environment" (Walsh & Tsurusaki, 2017, p. 36). Scaffolding, the raising of students' abilities through mentorship, facilitation, etc. and helping students to achieve their *zone of proximal development* (Vygotsky & Cole, 1978; Reiser & Tabak, 2014), can be very supportive of enriching personal and group contexts by enriching schema through the development of expertise (Goldman, 2001). Connecting to context to motivate students is a significant piece of this puzzle, but certainly not the only one.

The process to connect students to STEM-related disciplines, interests, and activities is not simply an academic exercise; it is an effort to inspire future generations to continue the innovative spirit that John F. Kennedy invoked when he insisted that Americans land on the moon by the end of the 1960s. It is the crucial work of forging, through STEM education, the next Steve Jobs, Mae Jemison, Neil deGrasse Tyson, or Marie Curie and of guaranteeing future generations the technological advances that postwar generations have enjoyed. The more students identify with a discipline such as science or mathematics as a part of their identity, the deeper their potential involvement in related activities (Van Horne & Bell, 2017). Recent STEM pedagogy links interest development, particularly for marginalized and stereotyped youth, to a social, interactional process that is ". . . often mediated by how students perceive the valued ways of knowing and being of a given practice or discipline in relation to the ways of knowing and being with which they already identify" (Pinkard et al., 2017, p. 481). This perception of a subject area like STEM can be enhanced through self-actualization by pursuing expertise in a particular STEM-related field, ideally facilitated from existing experts. The next challenge becomes effectively exploring that field.

Internet Search and STEM

When students search for information, they engage in "forming new constructs and altering those previously held" (Kuhlthau, 1989). As students realize the problem they face, in other words the information gap they need to fill to complete their assignment, they encounter a ". . . recognized anomalous state of knowledge (ASK), which, further modified by linguistic and pragmatic considerations, becomes a request put to the IR [Information Retrieval] system" (Belkin, 1980, p. 135). Thus, a communication is established between the technology that retrieves the information and the user who requests the information (Belkin, 1980). Students must learn to navigate difficult terrain in the Google era, acting and being acted upon by forces both inside of their personal experience and from external, societal forces (Schutz & Luckmann, 1973).

As students encounter gaps in their "stock of knowledge" (Schutz & Luckmann, 1973, p. 100), learning and attempt to fill those gaps become the primary goal. However, there are limiting factors to the stock of knowledge such as situation, spatiality, temporality, and social arrangements (Schutz & Luckmann, 1973). Temporality suggests that time is a factor in information behavior concerning searches and that the search and the searcher are interrelated (Beheshti et al., 2015). Since searchers can only assimilate a certain, finite amount of information in a search session, they purposefully construct meaning by choosing those slices of information they know and scaffolding new information to them (Kuhlthau, 1991).

Kuhlthau's (1991) model of information search process (ISP) (see Appendix) can be useful when examining interest development. This is uncharted territory, so future work will focus on the ways in which the process of interest development, from initial, situational, extrinsic trigger, to well-developed individual interest, mirrors the temporal, cognitive, and affective processes through which students search for information. Students perform many of the same tasks, e.g., search, documentation, vetting, and sharing, in both learning situations, and there is much to be gleaned by this cross-pollination. Interest is inextricably linked to value (Ryan & Deci, 2017), and examining how that value is viewed by students from elementary to university levels (Wyss, 2013) is crucial to understanding how to teach with interest in mind.

Kuhlthau's work acknowledges and embraces the roles that behavior and emotions play in information search. Kuhlthau accepts that searchers feel human emotions and experience human behaviors. They are frequently not the bold adventurers educators strive to create, opting for safety, ease, and comfort over completeness and thoroughness, choosing the known over the unknown. Kuhlthau boldly makes it one of the features of her model: "An information search is a process of construction which involves the whole experience of the person, feelings as well as thoughts and actions" (Kuhlthau, 1991, p. 362). Activating and building rich contexts for interpreting information using familiar concepts and constructs are the user's natural tendency, so the richer and more diverse the students' contexts, the more potential connections can be made. This is directly related to the socioeconomic gaps discussed earlier; the more STEM literacy one can build outside of the traditional learning environment, the more accessible STEM experiences become (Falk & Dierking, 2016). Once again, building context, especially for students with limited science literacy context, introduces STEM experiences and interests. Additionally, the incorporation of personal construct theory, describing the affective experience that accompanies meaning construction, into the ISP model represents a leap in information search understanding as the fields of information processing, education, and psychology cross-pollinate. If a particular student is not cognitively connecting, enjoying, or appreciating a STEM subject, field, or lesson, there is a model to express that affective and behavioral experience, target that moment of disconnection in the process, and potentially influence it with an intervention involving STEM.

The criteria for making these choices (search choices across the affective, cognitive, and physical realms) are influenced as much by environmental constraints, such as prior experience, knowledge, and interest, information available, requirements of the problem, and time allotted for resolution, as by the relevancy of the content of the information retrieved (Kuhlthau, 1991, p. 362). Personality traits also influence information-seeking attitudes and behavior (Halder, Roy, & Chakraborty, 2010), and although they cannot be predicted, they can be considered in a full model like Kuhlthau's ISP that offers insight into cognition, affect, and especially behavior: "The inner traits and personality dimensions of the information seekers interacts with the contextual factors to formulate the impact in the form of motivation for information, information habits, patterns of information seeking, and the nature of cognitive, affective and social utilization of information" (Halder, Roy, & Chakraborty, 2010, p. 43).

Improving Instruction Through Interest

Since interest plays such a significant role in learning, curricula and lessons containing interest-generating activities should be incorporated into learning environments to generate more authentic learning experiences. Teaching for conceptual understanding takes precedence over content-based or unauthentic activities (Fosnot, 1992). Furthermore, since learning extends over multiple years, educators can consider and reconsider how topics are presented at each grade level each year, building on prior understanding and supporting increasingly complex concepts (*Next generation*, 2013).

School library media centers should be the vanguard in the battle to educate and enhance our students. Interest, context, and engaging learning experiences are all available at the media center. The best school librarians are change agents, dynamic forces for multiple literacies in their buildings (Harada & Hughes-Hassell, 2007). Librarians are uniquely qualified to empower students to flex their research muscles by simultaneously learning about sourcing and doing it, confirming while learning, and increasing self-efficacy through increasing expertise. Reflection becomes a crucial part of this process, and students improve their visions of their projects and thereby gain expertise in their area by frequently looking back at the process they followed and the ways they thought about both the content and the process. Also, English language learners are recognized, and the contexts in which students process information are important to recognize and acknowledge as an inescapable part of the learning process. School librarians become not only collaborators; they become advocates for their students, staff, and community, embracing democratic principles and equity for all as they generate interest in STEM, also for the benefit of all (Harada & Hughes-Hassell, 2007). Most importantly, interventions featuring the *Four Phases of Interest Development* (Hidi & Renninger, 2006) have the potential to affect student career choices, depending upon factors such as specific content presentations and career promotions (Abbott, 2017), so STEM focus and research are not only relevant, it is necessary to achieve the long-term goal of having a society prepared to meet its scientific challenges moving forward (Wyss, 2013).

The school librarian should be the captain of the research team, the conduit through which the direction of projects flow. Subramaniam et al. (2015, "Role") present a case for ". . . the unique contributions that [librarians] can make to young people's learning of science" (p. 3) and other STEM fields. This is the link to librarianship that drives this study. Most students can Google an answer, but concerns arise about unprepared STEM researchers in a *project-based learning* (PBL) environment that stresses the use of technology, sourcing, and collaboration among class members and potentially others: Who is teaching them to self-reflect, and what is the value of reflection? Who is teaching resource and content vetting? (Harada, Kirio, & Yamamoto, 2008). Specifically addressing middle-level students (ages 8–12), Subramaniam et al. (2008, "Tween") argue for new digital literacy programs in an environment more conducive to ". . . building on tweens' existing heuristics and thereby resulting in strategies that are simultaneously compatible with their natural inclinations within the online environment and likely to consistently lead them to accurate credibility-related judgments" (p. 550). Subramaniam et al.'s (2015, "Bit") study illustrates the digital divide, perpetuated by socioeconomic factors, that still exists. Such gaps as the lack of on-grade literacy and reading skills, lack of effective methods to assess online credibility, and lack of interest in accuracy in favor of search result matching key phrases stultify the effectiveness of research and learning. This is a time when school librarians are needed more than ever to teach and promote digital literacy as effective teachers (Mardis, Kimmel, & Pasquini, 2018). The problem with school librarians as school leaders and teachers is that few administrators understand and appreciate what school librarians can do and what they are capable of bringing to schools (Mahoney & Khwaja, 2016), so it is unlikely that they will be assigned leadership roles unless they advocate so much that they are unable to perform their daily duties. Although school and district leaders may value media literacy, concerns about lack of funding, teacher training, and an uneven spread of technology across the district are still major factors in decision-making (Mahoney & Khwaja, 2016). Time constraints on teachers and school librarians hinder collaboration (Rawson, Anderson, & Hughes-Hassell, 2015). Also, school librarians are not always encouraged to teach.

Defining the role of school librarians in enhancing science learning, Subramaniam et al. (2015, "Role") conclude that school librarians should be playing a greater role in science learning because they can:

1. Encourage young people to engage in authentic inquiry practices by teaching them about information search models and strategies
2. Engage young people's everyday life interests by linking science learning to media and technology that appeals to them or they "see themselves" in
3. Promote the norms of ethical and social interaction in sharing science knowledge (p. 10)

As much as educators may want to offer choices to their students and facilitate their journey through them, curricula, instructional strategies, and objectives are often imposed on students and staff from outside. However, this reductionist approach cheats students of an opportunity for self-efficacy and identity construction (Winn, 1992). The work of Piaget supports construction of identity and self-efficacy through interaction with the environment and growing, developing, and evolving within it, reinventing and reorganizing information and understanding along the way (Fosnot, 1992). As students progress through Piaget's stages from concrete understandings to symbolic representations of those understandings, to abstract models, they learn structure, order, and reflection, then through interactions with others at which time their understandings change again (Fosnot, 1992). This is the process through which students come to own their research and their skills, fostering a growing curiosity that serves students well and leads to engagement and interest (Kuhlthau, Caspari, & Maniotes, 2015). This growth often occurs in what Kuhlthau (1991) calls a "third space," a socially constructed learning space in which ideas and creativity brew and steep, becoming artifacts, more fully-realized understanding, or ideally, both. Interest development occurs on a parallel course with cognitive development as knowledge grows and new information is scaffolded onto existing knowledge (Kuhlthau, 1991; Reiser & Tabak, 2014).

Conclusion

According to a 2018 National Science Foundation report, individuals born outside of the USA accounted for 29% to 30% of college-educated workers employed in science and engineering occupations in the USA, and this statistic has consistently risen over time (National, 2018). Although this trend demonstrates that many people want to work and live in the USA, it should also serve as a reminder that other countries are innovating and funding STEM education and research, producing leaders at a greater rate than the USA (National, 2018). Competition for top STEM employees is becoming increasingly fierce worldwide. Learning more about what interests students in STEM and developing best practices for curricular interventions are not only important, it may be a crucial step in ensuring that the USA remains competitive in a STEM-rich world.

Appendix

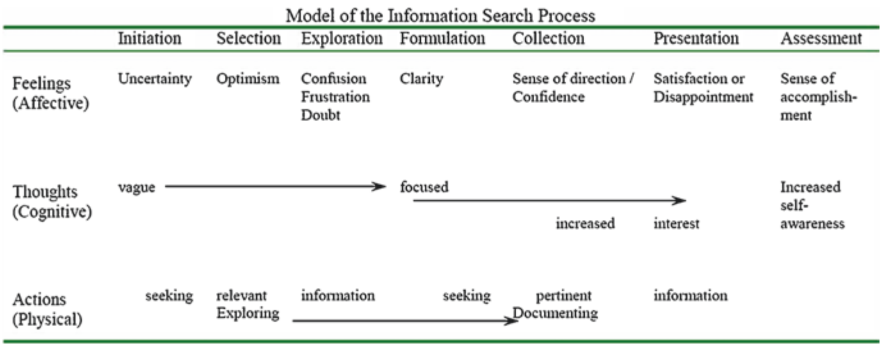

Chart 1 Kuhlthau's (1991) 6-stage, 3-domain ISP model

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Designing for Generative Online Learning: A Situative Program of Research

Grant T. Chartrand, Christopher D. Andrews, and Daniel T. Hickey

Education scholars have applied the theoretical concept of situativity to help explain and promote generative learning, whereby learners develop meaningful connections between knowledge and experience that transfer to subsequent settings (Greeno, 1997, 1998; Greeno & Engeström, 2014). While interest in fostering generative learning has a long history in education research (e.g., Wittrock, 1974; Fiorella & Mayer, 2016), recent consensus on advancements in our understanding of learning (National Research Council, 2000; National Academies of Sciences, Engineering, & Medicine, 2018) now informs the education research community that transfer is supported when learners understand the general principles underlying the original learning situation and then connect that knowledge with a transfer situation. This development of deep understanding enables learners to identify the structures in the present learning domain, which enables them to identify invariant (i.e., constant) characteristics of subsequent transfer domains (Greeno, Smith, & Moore, 1993; National Research Council, 2012).

The situative perspective considers knowledge as being distributed across people; the objects they use such as books, tools, computers, artifacts, etc.; the physical and social environment; and other contextual factors that influence activity. The multitude of interactions that take place in these systems can also help explain this learning process in that learning occurs when one engages in disciplinary practices and discourse (Greeno, Collins, & Resnick, 1996) when instruction is contextualized (i.e., framed) using meaningful problems and examples. Many who embrace the situative perspective come from fields such as education, anthropology, design, linguistics, and computer science. These interdisciplinary researchers argue that generative learning is most likely to occur when learners make connections between

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past and potential future contexts and consider how disciplinary practices have and could be used.

There is prior research on situative theories of knowing and learning by instructional design and educational technology scholars (Winn, 1993; Choi & Hannafin, 1995; Young, 1995; Hay, 1996; McLellan, 1996; Herrington & Oliver, 1999; Hung, Looi, & Koh, 2004; Angeli, 2008; Henning, 2013). This chapter will expand on two interdisciplinary ideas that come from the situative approach: *productive disciplinary engagement* and *expansive framing*. Furthermore, this chapter presents an interdisciplinary research program that extends expansive framing and productive disciplinary engagement into online contexts where many educators find generative learning elusive and where framing of learning is crucial. With the exception of Fasso and Knight (2015) and Mendelson (2010), a search of the published research failed to locate studies of productive disciplinary engagement and expansive framing in online course contexts beyond our own ongoing research (e.g., Andrews, Chartrand, & Hickey, 2019). Fasso and Knight as well as Mendelson apply expansive framing in their post hoc analysis of the teaching and learning that occurred in their studies. In contrast, Andrews et al. (2019) used expansive framing to inform curricular design and analysis of student interactions. Instructional designers and educational researchers should find this latter approach particularly informative for their research and practice.

Framework

Randi Engle, drawing on situative approaches to learning, proposed productive disciplinary engagement (Engle & Conant, 2002; Engle, 2012) and expansive framing (Engle, 2006; Engle, Lam, Meyer, & Nix, 2012) as pedagogical frameworks to foster generative learning. Both ideas have been studied extensively in the learning sciences but mostly in conventional STEM classrooms (Forman, Engle, Venturini, & Ford, 2014). These two concepts approach knowing and learning from the learner's perspective as a starting point for understanding course content, promoting engagement, and supporting generative learning. Lobato (2012) offers a similar perspective in research on *actor-oriented transfer*.

Productive disciplinary engagement. Engle and Conant's (2002) initial framework of productive disciplinary engagement is an approach that designers can use to create generative learning environments. In productive disciplinary engagement, the learner's experience is the starting point for engaging with to-be-learned concepts. Productive disciplinary engagement is best understood by highlighting the distinctions between *engagement*, *disciplinary engagement*, and *productive disciplinary engagement*.

First, engagement is understood by analyzing learners' participation, interactions, and responsiveness. Learner engagement can take many forms: (a) contributions made in coordination rather than independently, (b) few learners involved in unrelated "off-task" activities, (c) attentiveness to one another, and (d) learners' arguments are connected with and draw support from their perspectives and/or positions (Engle, 2012). In an online environment, engagement can be responding/referencing peer entries, sharing/linking outside resources, and learners independently starting coursework. In some instances, learners quickly take up these forms of engagement after instructors briefly model how and when they want their students to do so.

Second, for engagement to be disciplinary, activities should touch upon and support learners working toward embodying the issues and practices of a discipline's discourse (e.g., science learning by taking up the skills and practices used by scientists vs. science learning by following typical school and classroom practices). While no instructor or course constitutes a discipline, the ways of knowing and learning that generally make up a discipline should involve shared social, material, and rhetorical practices (Ford & Foreman, 2006). When learners engage in these "authentic practices," they are more likely to understand the core disciplinary ideas and concepts embedded within those practices and are then able to use that knowledge in subsequent situations (Brown, Collins, & Duguid, 1989).

Finally, disciplinary engagement is considered productive when it continually advances the intellectual quality of learners' practices over time. Productivity depends on the discipline, task, topic, and progression of the learners (Engle & Conant, 2002). Learners' practices, for example, should develop from low-level procedures such as *sharing* initial ideas to mid-level *comparing* and *evaluating* sequences and eventually toward high-level *challenging/debating* and *synthesizing* routines. This progressive evolution should transition learners from basic, peripheral participation toward more advanced forms of generating and contributing new arguments, new questions, and new ways of engaging with the discourse and content. Instructors should facilitate activities that allow learners to lead their own discussions, debate among themselves, collaborate with one another, and communicate their understanding.

The initial naturalistic characterization of productive disciplinary engagement evolved into a set of widely cited design principles (Engle & Conant, 2002) for fostering generative learning. The following principles provide a useful structure for instructional designers who want to improve their learning environments and for researchers who are searching for new ways to analyze disciplinary ways of teaching and learning:

- **Support learners as they "problematize" curricular concepts and take on problems from their perspective.** Rather than having learners simply observing and passively soaking up information, instructors and instructional designs should enable students to pose questions, submit proposals, challenge ideas, and offer other contributions to learning. Problematizing curricula can help learners articulate their reasoning, identify gaps in thinking, and surface disagreements in understanding (Reiser, 2004). It is worth noting that this is not the same as the constructivist precept that learners' prior knowledge is the starting point of instruction.

- **Give learners the authority to define, address, and resolve problems as stakeholders, contributors, and experts.** Give learners the authority to deeply engage with problems rather than going through the motions. Here the concern is empowering learners to take an active role (i.e., agency) in making consequential decisions for learning, transitioning toward emerging experts (Gresalfi, Martin, Hand, & Greeno, 2009; Lindgren & McDaniel, 2012).
- **Learners are accountable to each other, to other stakeholders, and to disciplinary norms**. Encourage learners to hold themselves and each other accountable for extending and building upon shared knowledge. Their work is responsive to norms within and outside the learning environment as well as to disciplinary experts. Learners are expected to collaborate and respond to each other (Zhang, Scardamalia, Reeve, & Messina, 2009; Scardamalia & Bereiter, 2014).
- **Provide access to adequate resources to enable learners to embody the previous three principles**. Provide adequate resources for learners to productively engage with the problem at hand. The learning environment and instructional decisions must afford ample time, adequate space, access to necessary tools and information, and contact with experts. Instructors also need to be aware of the learners' backgrounds, the instructional goals, and the topic choice in order to arrange for and scaffold appropriate resources.

When creating course activities, instructors and designers should integrate all four productive disciplinary engagement design principles. For example, activities should be flexible so that (a) learners can align course content with their own interests without affecting the integrity of the learning outcomes, (b) learners feel free to make such changes, (c) learners expect one another to fully engage with the activities, and (d) the instructor allows learners to fully engage with the activities.

Expansive framing. Engle's subsequent notion of expansive framing provided further guidance for fostering productive disciplinary engagement and generative learning (Engle et al., 2012). Learners are first asked to think and reflect expansively on course content and then asked to make connections between course content (i.e., learning context) and personal and meaningful experiences (i.e., transfer context). This relates to problematizing content in that learners are encouraged to consider their own experiences in relation to the subject matter and ideas presented in the course. Expansive framing pushes learners to think and connect ideas, while supporting reflective inquiry; knowing and learning are situated in one's experiences and personal context.

Expansive framing contrasts with cognitivist notions of transfer, which argue that subject matter and content to be learned must first be sufficiently and independently abstracted, understood, and mastered (National Research Council, 2000; Day & Goldstone, 2012). Whereas the cognitivist view emphasizes the use of cognitive structures and mental representations, the situative view focuses on an individual learner's experiences and interactions and how they are shaped to participate and act (Greeno, 1997, 1998). One's background and context are not separate from learning; this perspective treats both as vital to learning, so that learners insistently use their knowledge and relevant experiences to help construct meaning and understanding.

Engle (2006) and Engle et al. (2012) contended that when learners think and reflect expansively, they extend their understanding to situations beyond the bounded confines of a course (e.g., extending to other people, places, topics, and times). In expansive framing, the social situations that involve other people, places, topics, and times are used to frame one's engagement and understanding with course content. Instructors ask learners to reflect on and connect with these contextual aspects so that they can reframe and problematize content in ways they find relevant. It is this (re)contextualization that is theorized to support truly generative learning. Encouraging learners to engage in the course content through the lens of their relevant contexts also enhances their agency in the learning process. Instructional designers and researchers can incorporate expansive framing into their learning environments by organizing activities that ask learners to connect their experiences with course content around the following framing aspects:

- **Participants (people)**. The activity is relevant to a broad community that extends beyond the course. Learners consider their interactions with their peers and other people.
- **Places**. The activity is relevant to other contexts (i.e., other courses, out of school, at home, at work) outside of the course. Learners draw on experiences from other situations during the ongoing activity or envision other situations where the knowledge can be applied.
- **Topics**. The activity relates to non-course subject areas and topics. Learners connect the current lesson and other course ideas with external corresponding lessons and course ideas that they are currently studying, have studied, or will study.
- **Times**. The activity can be linked to past or future instances. Learners draw upon prior knowledge during an activity or envision future applications of using the current course content.

In addition to the four framing aspects elaborated above, two additional aspects, authorship and accountability, were initially discussed by Engle et al. (2012) as consequences of positioning learners. These two aspects were further explicated by Andrews et al. (2019) and were used to help learners contextualize their engagement with course content:

- **Authorship**. Learners are authors who are responsible for developing, sharing, and defending their ideas. Learners are open to build upon the ideas of others.
- **Accountability**. Learners are members of a community who feel accountable and hold their peers accountable for developing, sharing, and defending their ideas. Learners directly engage others and encourage productive discussions.

Learners who apply the six framing aspects described above foster engagement and understanding of content, which is thought to lead to productive disciplinary engagement. Learners can also expansively frame course content using multiple aspects. For example, a learner may reflect on an idea being discussed in the present by connecting it to similar ideas from a previous course taught by another professor, while also contemplating future applications of that idea. Such a frame would cover times, topics, and participants. Expansive framing can also occur in succession with students engaging with one another. Students responding to the first example could exhibit authorship and accountability aspects by building on the first example's ideas and reference additional aspects in their responses.

Expansive framing encourages learners to continually think about and make connections between course content and their own experiences. This process of repeatedly extending back and forth between the learning and transfer contexts creates an encompassing context called intercontextuality (Floriani, 1994; for intertextuality see also Bloome & Egan-Robertson, 1993; Kumpalainen & Sefton-Green, 2014). Intercontextuality describes the relationships between different sociocultural contexts across places and times, and it occurs when two or more contexts become linked with one another. When both learning and transfer contexts are linked, content from the learning context is considered relevant to the transfer context. Thus, the more related that learning and transfer contexts are considered to be, the more likely—all other things being equal—that students will transfer content between them.

In this regard, intercontextuality involves a learner's prior contexts, other current contexts, and perceived future contexts growing and forming robust connections. As learners begin to connect with ideas from the course, they also begin fostering intercontextualities. Engle (2006) suggested that as learners apply expansive framing and establish links between current learning and future contexts of use, they are then able to perceive both contexts as relevant to each other. Consequently, expansive framing pushes learners, while also priming their growing understanding to perceive yet even more possible connections to yet even more transfer contexts (Greeno et al., 1993).

Program of Design Research and Example Study

This program of research was initiated around 2007 when the third author began teaching online graduate courses in education. Hickey and Rehak (2013) detailed their efforts to adapt the structure and function of wikis to student-generated course work, which they called "wikifolios." In their work, Hickey and Rehak asked students to define a personally relevant instructional goal and educational context in which to problematize course content. In each subsequent assignment, students would post a public (to the class) wikifolio where they would consider the relevance of new content to their framing context. In marked contrast to most online courses, course content was not discussed in typical discussion forums; rather, content was discussed in threaded discussions posted directly on student wikifolios. Within these comments, instructors' comments serve a crucial role of positioning student engagement to make it more productive and more disciplinary.

As elaborated in Hickey, Chartrand, and Andrews (2020), a new framework for online learning emerged in this work. This framework embedded the design principles for using expansive framing to foster productive disciplinary engagement with the three "levels" of assessment that had emerged in a prior program of design-based assessment research (Hickey & Zuiker, 2012). Deemed participatory learning and assessment (PLA), this framework embeds productive disciplinary engagement within three levels of increasingly formal assessments. These include public reflections on engagement, private formative self-assessments, and discreet automated achievement tests. Because the reflections serve as summative assessments of engagement, the instructor can use them to (privately, but very efficiently) assign points for that engagement. This minimizes private instructor feedback, allowing instructors to spend nearly all of their time engaging in public threaded discussion where they can position (and reposition) student engagement in support of productive disciplinary engagement.

As part of this ongoing program of design research of online instruction, the second author used expansive framing to support productive disciplinary engagement in the design of an online educational psychology course for physical education, visual arts, and world language pre-service teachers (Andrews et al., 2019). Instead of "wikifolios," students annotated course readings using a social annotation tool called *Hypothesis*, which allowed participants to have threaded discussions directly on the course readings. During the semester course, students generated 459 comments; more than 95% of those comments referenced at least one aspect of expansive framing, and 62% referenced multiple aspects of expansive framing and provided specific examples connected to those aspects of expansive framing. This study also found that students who took up expansive framing in their threaded annotations performed better on the written final exam ($r = 0.56$, $p < 0.05$). Qualitative analysis showed that when students' annotations connected course readings to pedagogical practices in their own content area or to general pedagogical practices (i.e., problematizing), student responses generated rich dialogue. In these annotations, students often positioned themselves as "future teachers" by generalizing the course content to their future pedagogical practices. This positioning and generalizing have been shown to help shape future classroom practices (Lee & Schallert, 2016) and enhance transfer more generally (Gick & Holyoak, 1983; Salomon & Perkins, 1989).

Analysis in a follow-up study (Chartrand, 2020) is underway on an additional 20 students enrolled in the same course the following year. These students also used Hypothesis to annotate assigned readings and reflect on their own and their peers' comments in weekly posts. This follow-up study is examining (a) to what extent students hold each other accountable, (b) to what extent students exhibit the role of being an author, and (c) how accountability and authorship aspects factor into learning outcomes such as final course grades.

Implications for Interdisciplinary Learning

Like the widely used funds of knowledge approach (Gonzalez, Moll, & Amanti, 2005), the PLA framework uses learner diversity as a pedagogical asset. The framework furthermore avoids engagement routines and discourages student engagement that frames any diversity as a "deficit." In most course contexts, there will be disciplinary differences across students that can and should be exploited to help problematize course content. For example, as described in Hickey and Rehak (2013), students in an online course on learning and cognition in education self-selected into informal "networking groups." These groups were organized around the five "cognition in the classroom" chapters in the last section of the textbook (literacy, comprehension, writing, math, and science). During each of those five weekly assignments, students in the corresponding networking group completed a relatively extensive collaborative assignment. Students in the other four groups were asked to identify the most relevant aspects of that chapter for their own context. This helped students in the other four groups to problematize their engagement with a chapter that might have otherwise seemed irrelevant. This framing in turn fostered additional obvious opportunities for interdisciplinary productive disciplinary engagement within and across groups.

It turns out that seemingly small differences in disciplinary orientation between learners can be used to help problematize disciplinary knowledge. Consider, for example, students in the educational psychology course for physical education, visual arts, and world language pre-service teachers as explored in Andrews et al. (2019). Students bring their disciplinary orientations from physical education, visual arts, and world language contexts in addition to their personal histories and contexts; this interdisciplinarity of perspectives enables students to reveal certain nuances of the course content that may go unnoticed. Perhaps most important, even if students fail to uncover differences, the search for those differences will almost certainly frame their engagement with the content expansively, along with any corresponding discourse.

Impact and Conclusion

The studies summarized in this chapter are part of an ongoing program of design research to transform the design principles of productive disciplinary engagement and expansive framing from their original conception as *pedagogical tools*, used by instructors to encourage learning, into *learning tools*, used by learners to promote their own generative learning. This reconceptualization prioritizes learners' agency and enables them to direct their own learning as they work toward establishing their professional identities.

Designers and technologists should consider the role of framing discourse and how learners can be encouraged to make connections with course content across their individual experiences and educational, professional, and personal contexts. Having learners deliberately and meaningfully frame their own connection is important, especially in online contexts where content is typically designed and finalized beforehand. Moreover, instructors cannot quickly frame content for each individual learner during online discussions.

We present this chapter on our program of research on productive disciplinary engagement and expansive framing for online learning in hopes that instructional designers and researchers will find the use of the related design principles, social annotation, and the studies discussed to be informative for their research and practice. It is worth noting that it was not particularly complicated or laborious to set up and implement the curricular routines discussed, and it could be used in fully online as well as hybrid course contexts (Hickey et al., 2020).

Consequently, designers and technologists may find that reengineering their current discussion tools to further support learner interactions and connections of this nature to be worthwhile. Tools like Hypothesis are well-suited to help promote interactivity and networked discourse, and they can be impactful for research. Social annotation data can be used to help researchers identify additional sources of information beyond expansive framing and social, collaborative, and other participatory interactions (Chen, 2019; Kalir, 2019).

Other ongoing work that extends the issues discussed in the context of this chapter includes (1) examining the consequences of social annotation use on disciplinary artifacts (i.e., course readings, support documents); (2) fostering consideration of social justice (e.g., diversity, historicity, and identity; see also Agarwal & Sengupta-Irving, 2019) and how learners might frame their engagements with these considerations; (3) more deeply examining other aspects of expansive framing (such as accountability and authorship) in online learning; (4) examining the factor structure of a new *Expansive Framing Survey* completed by over 6,000 students as experimental items alongside that 2019 National Survey of Student Engagement; and (5) comparing the relationships between scores on the survey and other course outcomes (e.g., near and far learning transfer, satisfaction, etc.) with relationship between scores on the widely used Community of Inquiry survey (CoI; Arbaugh et al., 2008) with those same outcomes.

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Instructional Design and User Experience Design: Values and Perspectives Examined Through Artifact Analysis

Elizabeth Boling and Colin M. Gray

At a high level, design activity may be understood in similar ways, wherever it is practiced (Cross, 2007; Goel, 1995; Nelson & Stolterman, 2012). Design scholars do not claim that the same process models are used by all designers but that conceptual descriptions of design are essentially the same from one field to the next and that design knowledge and action can be studied in a general and transdisciplinary sense.

At the *highest* level, there are differences from one field to another, or within a single field, in the values (represented as philosophies) and resulting perspectives that affect design practice. These may be identified with individual designers like Mies van der Rohe whose *less is more*philosophy of design permeated his work and his teaching (Carter, 1999); Victor Papanek, who pioneered and taught a philosophy of humanitarian design (Kries, Klein, & Clarke, 2018); and Dieter Rams of the functionalist school of product design espousing a *less but better* philosophy (Klemp & Ueki-Polet, 2015). A philosophy of design may, alternatively, be pervasive and expressed as the default across a field of design—as is the case for instructional design where efficiency and effectiveness (and sometimes appeal) are rarely questioned as the foundation of our values (Reigeluth & Carr-Chellmann, 2009; Smith & Boling, 2009; Merrill, Barclay, & van Schaak, 2008).

Designing, which occurs to a large degree through language (Cuff, 1991; Fleming, 1998; Olson, Olson, Carter, & Storrøsten, 1992; Waters & Gibbons, 2004), can be difficult, owing not only to different perspectives on methods, representations, processes, and work practices but to differences in value assumptions (Bucciarelli, 2002). These languaging features of design are fundamental and

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therefore hard to recognize or change (Nelson & Stolterman, 2012). We argue that differences in language use may additionally be hard to identify in closely related fields, such as instructional design (ID) and user experience design (UX), when collaborators are speaking in similar terms and using familiar practices—or are simply assuming that they are working from similar premises (Hey, Joyce, & Beckman, 2007; Kolko, 2018). Further, we assume that time may be lost, that barriers to collaboration may be present, and that design outcomes may be affected negatively when values and perspectives are not aligned—or at least recognized—among designers; hence our motivation to carry out a detailed, cross-disciplinary artifact analysis as a method for identifying and surfacing illustrative similarities and differences in the values and perspectives of the designers who created those artifacts. We use *artifact* here as a term denoting an object, system, or experience that has been intentionally created; artifacts in this view may be tangible or intangible. We are, furthermore, interested in the potential for new conversations and understandings to arise from this, and perhaps other analyses, rather than creating conflict around differences in the values permeating various fields of design.

Artifact Analysis

"… the knowledge of a historic designer, embodied in [their] products, remains, even though the designer may have passed away long ago. Using that physical knowledge and re-engineering it from the object, seems to be a very promising method for extracting knowledge" (Müller & Thoring, 2010; p. 3).

While the analysis of an artifact can be conducted in a functional way, taking the form of an analysis that describes how it works or how it is put together, an analysis may also be carried out conceptually through a deconstruction in which factors such as "a sense of the product's design inspiration and philosophy … salient aspects of the product design, which ranges from form and function to marketing and socio-historical context" are interpreted from artifacts by experienced designers (Lidwell & Manacsa, 2009). In Fig. 1, we provide an example of this deconstructive analysis from Lidwell and Manacsa (2009) in the top two columns; further elaboration of the purpose of the annotated image and the annotations themselves appear in the two columns below, each referring to the one above it.

Analysis of an artifact may include discussion of its known, or presumed, positive qualities and its known, or presumed, shortcomings. Alternatively, analysis of an artifact be carried out as a means to interrogate the intentions and actions of the designer(s) creating the artifact. This second form of analysis is offered here for the purpose of illustrating not the values (or objective quality) of the artifacts but the values held by their designers—that is, what those designers consider to be important as evidenced in the decisions that clearly led to these artifacts existing in the forms that they do. This intentionality points to a form of design knowledge, underlying and informing all judgments made by designers, known as core judgment (Nelson & Stolterman, 2012). Core judgment, the least explicit but most pervasive

❹ The seat is effective at accommodating variable seating behaviors (e.g., lip sitting versus leaning back). The waterfall front edge of the seat reduces problems of circulation under the thighs, though it would benefit from a greater angle of attack. The span is limited in its capacity to offer varying degrees of support across the uneven surface of the human buttocks, making it less comfortable to many than its more traditional padded counterparts. That said, the aeration afforded by the pellicle is generally a good trade, as most will happily endure numb buttocks to avoid sweaty thighs.
❺ The mechanicals are largely exposed, giving the supporting structure an exoskeletal appearance. Take an organically designed object, paint it black, give it five legs, expose its mechanicals, subtract any semblance of padding, and you get a chair that is decidedly uninviting—it looks hard, arachnoid. This lack of *prima facie* appeal is quickly overcome, however, when a person sits in an Aeron, a requirement that is undoubtedly the greatest challenge of marketing this product.

The numbers called out from the image of the object refer back to explanatory text describing the object and some of the known or speculative factors involved in how it came to be designed as it was. Multiple academic and practitioner contributors supply this text.

The matrix of circles midpoint below the image of the object correspond to qualitative scores (1-4) on five dimensions: aesthetic, function, usability, sustainability and commercial success.

The visual symbols to the left and right of the matrix are described as "semantic icons …[to]… stimulate analogic thinking and ideation," (p. 10). Here it is possible to imagine references to the look of the chair as it was experienced in a market unfamiliar with this now-common profile (spider-like), to the ergonomic goal of the design (a measure-of-man reference to human factors), systematic or industrial design (gears), and bio-mimicry in design (jellyfish profile of large body on multiple, spindly "legs).

The explanatory text itself includes commentary on the artifact as it performs, as it may intersect with human physiognomy and psychology, and how it may have been designed to satisfy certain goals or criterion (as interpreted by the analyst).

At the back of this book the experiential, academic and/or laudatory bona fides of the commentary authors are given. The context of their commentary is, therefore, established for readers who can judge for themselves the intention and rigor of that commentary.

Fig. 1 Sample representation of one method for deconstructing (or analyzing) an artifact from Lidwell and Manacsa (2009) showing a representation of one artifact (upper left), sample explanatory text from the book (upper right), and description of analysis features by authors of this paper (lower two columns)

of the judgments at play in designing, is the view of the world inscribed into the artifact, including what is valued and—in the professional context—what is valued in the practice of that profession (Boling, et al., 2017). As a pervasive form of judgment, and an implicit one, core judgment is difficult to suppress in an artifact and likewise can be difficult to miss. Not knowing the individual designers and assuming the strong likelihood that teams of designers rather than lone individuals produce an artifact, we are, of course, not interrogating the personal values of individual actors. We hope to discern an impression of the professional values in play for designers we do not know, presumably absorbed from the fields in which they practice and manifest in the artifacts they have produced. This linking of artifact to potential authorial intentionality is a common practice in many creative fields, including comparative literature, art history, film studies, and linguistics.

Frameworks for Analysis

While the analysis is, evidently, subjective, this is not to say that it is *undisciplined*, either in the sense of lacking rigorous constraints or in the sense of standing objectively outside one discipline or another. It is both structured by the frameworks we are using *and* embedded in the domains of design from which each is drawn. In fact, our analysis is intended primarily to shed light back onto the frameworks, revealing the values embedded in them.

We selected two frameworks for interrogating these artifacts; *first principles of design* from instructional design (Merrill, et al., 2008) and *interaction criticism* from user experience design, as embedded within human-computer interaction (HCI) scholarship (Bardzell, 2011). These frameworks do not remove the subjective and speculative dimension of artifact analysis as we are conducting it; indeed, these very dimensions make such an analysis possible by supplying an overt means to maintain discipline in the content, scope, and focus of the analysis. Using more than one framework also affords a synthetic analysis, both leveraging our experiential knowledge in speculating about the designs and to some extent affording a stimulus for speculating on design moves in ways external to either of our own implicit value or disciplinary structures.

First Principles of Instruction

The first principles framework is argued to subsume multiple others in the field; since its introduction, it has been cited over 2500 times (Merrill, 2002). It is agnostic to learning goals or the type of material to be learned, which is actually the primary focus of many, widely used conditions-based frameworks for instructional design (Ragan & Smith, 2004).

The claim is made that other models include some or all of the five first principles and "do not incorporate fundamentally different principles" (p. 174) and, further, that when a "program or practice violates or fails to implement one or more of these underlying principles, there will be a decrement in learning" (Merrill, et al., 2008; p. 175). This is a prescriptive model, requiring that designers achieve the required characteristics of the design and assuming, therefore, that the result will be "efficient, effective and engaging instruction" (p. 182). The model does not address the larger context of instruction or directly address the individuals who are teaching and learning. The five requisite principles state that instruction must be task-oriented, activate prior knowledge, provide demonstration of skills to be learned, and offer opportunities to apply those skills and integrate them into the learner's everyday life.

Interaction Criticism

Bardzell's (2011) interaction criticism approach facilitates a critical exploration of the user experience, building upon insights from cultural studies for human-computer interaction (HCI) scholars and practitioners. Within the "interaction layer," a critic can describe the experience from multiple perspectives, including the designer, interface, user, and social context (Bardzell, 2011). Each perspective affords a different lens or point of focus through which the entire experience can be evaluated and described. All four perspectives can be viewed within a larger experiential mode (consistent with user experience design (UX) or with HCI) or within a learning-focused mode (consistent with instructional design (ID) or learning experience design (LX)), exposing different attitudes toward app-focused interactions and the broader purpose or intent of these interactions.

Method

We conducted this study as an exploration of values and perspectives embodied in designed artifacts and began by selecting two artifacts for the analysis—one created in the mode of direct instruction and one in the mode of what might be called performance support or task support. The artifacts were additionally chosen to be (1) accessible to readers of this study, if not directly, then as a class of designs with which many people are familiar, (2) focused on learning/performance support, and (3) amenable to representation in published form. Using these criteria, we chose two mobile platform apps, *Mathemagics-Mental Math Tricks*™ and *Photomath*™, as the focus of our analysis. The general descriptions of these apps are presented in Table 1. While these apps are similar to each other in the domain they both address, and both could be said to support either learning or performance, depending on their use, they are different in conception. *Mathemagics* offers a direct and intentional learning experience, while *Photomath* presents as a tool that may be used to solve equations, whether the user ever learns to do so independently or not.

We used a framework-driven analyses to interrogate these artifacts and then wholistic comparison and interpretation of these analyses. The argument for this form of analysis is laid out above. In the first stage, we interrogated these artifacts, Elizabeth using principles from instructional design and Colin using principles from UX design. We relied upon our own professional expertise in graphic design, interface design, experience design, and instructional design to apply the frameworks. Specifically, the activity of analysis consisted of refreshing our understanding of the

Table 1 *Mathemagics* ™ and *Photomath* ™ apps compared in terms of goals and primary features

App	Goals	Primary features
Mathemagics	Teach computational shortcuts for mathematical operations	3 modes Learn Practice Play Gamification Timed and untimed "play" Awards and points Self-paced Access to steps during practice No remediation Social media via leaderboards
Photomath	Based on photo or keyboard entry, solve equations entered by the user, showing the worked steps	Multiple forms of input/editing Each step explained Multiple levels of explanation Extensions to new problem types via push notification

selected frameworks (each of us being previously familiar with the one we used), engaging in several hours of purposeful interaction with the selected artifacts (which neither of us had used before), and taking notes during those interactions. Those notes, together with additional reference to the apps, we then used to address the elements of the frameworks in order to interrogate the designs repeatedly with the goal of describing the ways in which they embodied, or did not, elements of the frameworks. This was not an exercise in determining whether or not the apps conformed to the frameworks in an evaluative sense, but one in which we were applying speculation informed by our experiences as designers to the ways that value positions within the frameworks may have affected the designs of these apps. Our commitment was further to articulate the reasoning behind how we connected the experience of using the apps and the frameworks from different relevant disciplines and then the design values illuminated via those connections.

In the second stage of the study, the authors collaborated to meta-analyze these analyses, identifying points at which similar and different value positions and specific perspectives may have been in play during design. We drew on our backgrounds in both areas of design to explore the points of intersection and disconnect in the analysis, together with possible implications for collaborative design practice.

Analysis

Mathemagics

First Principles Analysis

This app is presented as explicitly educational, with the developers promising in their iTunes blurb that the problem-solving techniques it teaches will assist learners studying for standardized tests and naming both students and teachers as targeted learners. From a list of tasks (50 of them, starting with “Multiply as high as 19x19” and ending with “Check Division by Casting Elevens”), the learner selects one and the app provides a demonstration in the form of a single worked problem. Practice is provided via a sequence of problems in multiple choice format, with feedback limited to minimal right/wrong cues and access to the original demonstration screen if the learner wants it. There is no corrective feedback provided, although problems the learner solves inaccurately cycle back through and the practice continues longer if learner performance is poor. While the tasks presented do require activation of prior knowledge (specifically, basic computation carried out mentally), it is difficult to say that the instruction accomplishes or promotes that activation beyond assuming it has happened—and the skills cannot be learned without it. It is further assumed that learners can carry out, and remember, the required computations mentally; there is no provision for practicing and learning these component skills (Fig. 2).

The application of skill is provided for through quizzes and two forms of game (timed and untimed), all three structured essentially the same as the practice. Learners earn titles as they progress through levels of difficulty in the practice and

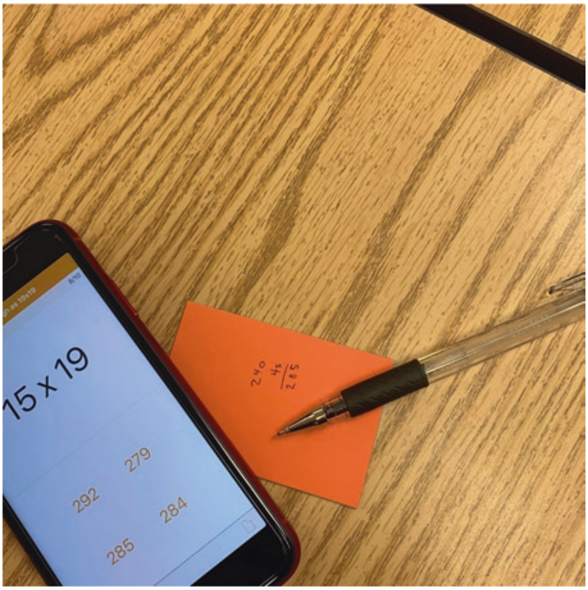

Fig. 2 Jotting down basic computation steps in order to practice the “magic” techniques for solving more complicated problems

the games, but they do not receive coaching at earlier levels of performance. While integration of the skills into learners' lives is promoted at the time the app is downloaded, there are no prompts for reflection or imagining possible uses of the knowledge during the learning experience. The opportunity for public demonstration of skill is present indirectly through the option to post one's scores on a leaderboard.

As an instructional design, *Mathemagics* is missing fully viable versions of features required under first principles: directed activation, either intrinsic or coaching feedback, and integration. Value is expressed, however, for the benefits of efficiency in problem-solving, the effectiveness of repeated practice to memorize a cognitively based process, and the contribution of extrinsic motivation to encourage practice.

Interaction Criticism Analysis

This app provides no onboarding but follows a lesson format that is familiar to students yet includes gamified elements to support mathematics learning. From the designer's perspective, the app promises to "amaze and delight others" and "tease your brain," while also pointing toward preparation for standardized testing. From a user perspective, the app is positioned toward students struggling with specific mathematical concepts—likely linked to learning outcomes for specific grade levels. Teachers also appear to be an implied user or stakeholder, due to the lack of structure around selecting and completing appropriate lessons. Both audiences are mentioned briefly in the app description, with the promise of "baffl[ing] your math teachers" for students and the promise of "inspir[ing] your students" for teachers. The lesson titles are written in instructional language, requiring students to identify gaps in their mathematics knowledge, express this gap in instructional terms, and then select the appropriate lesson title. This appears to link to social context expectations on the part of the app designer that the user is engaged in formal mathematics instruction. While a user might go through the lessons in turn, the lessons do not appear to be sequenced or grouped in any specific way. Thus, it seems likely that the implied social context is that student would be gradually led through a series of mathematics concepts in the classroom that could be enriched through targeted use of the app.

From an interface perspective (Fig. 3), the app facilitates three parallel task flows, structured around learning, practicing, and playing. The interface is confusing, with no clear indication of the purpose of the app or what task flow might be initiated by each button. The practice and play flows are almost identical, with only minor differences in the number of questions and the play modes. The elements from the "learn" section are visible in the practice and play flows by selecting a button. The user flows appear to assume progression from learn to practice to play, as the user becomes competent in the mathematics techniques provided, but this progression is never articulated in the app. The play mode also offers no direct way to check performance, requiring the user to manually check their progress under "Stats" to see if they answered the question correctly. Some scaffolding is built into the practice mode, where users selecting an incorrect response are provided a

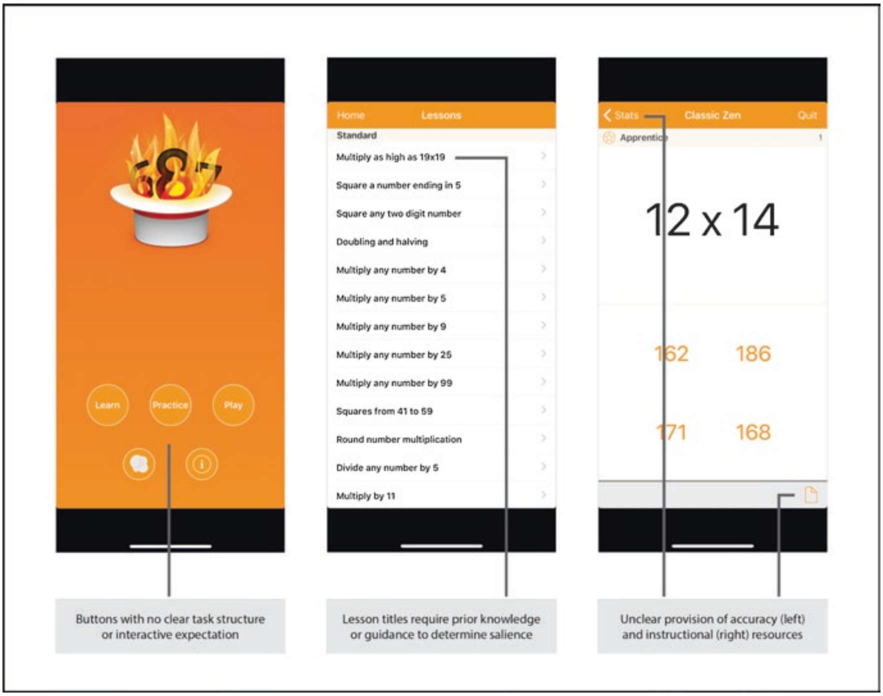

Fig. 3 Annotated screens from the *Mathemagics* app

microinteraction that keeps them from selecting that answer. However, none of these interactions are clearly indicated by appropriate affordances and signifiers.

From a user experience perspective, *Mathemagics* offers a confusing and unintegrated set of tasks that appear to rely on external sources of support by other stakeholders. The lesson names are not accessible to the target group, and the links (both interactive and user interface) between learn, practice, and play are unclear.

Photomath

First Principles Analysis

This app is wholly task-centered, and it utilizes *whole tasks*, complete equations entered either by translation from a photo or by manual entry.

Demonstration is provided through displaying step-by-step solutions, which means that component skills are thereby also included. While prior skills may be activated, particularly at the lower levels of explanation (which are presumably close to a learner's existing skills), everything, including some media in the form of graphs, is presented as additional demonstration. Terms a learner does not know, and presumably the skills they represent, are explained through what is termed the "Detailed view." This view breaks the skill down to a finer-grained component skill until the learner arrives at a basic computation which appears to be an assumed skill (Fig. 4).

As the equations entered into the program are solved immediately, neither direct practice nor feedback are offered to a learner—only demonstration. It is possible, however, to apply any skills being learned or brought to the app, by editing equations that have been entered and observing the resulting changes in how they are solved. Equations and their solutions may be saved in a history, potentially offering some integration into the learner's life. There is no provision in the app, though, for considering how this integration might be accomplished or for demonstrating one's new knowledge—assuming new knowledge has been acquired through studying the solved equations. It may be possible to argue, however, that integration is built into the app because nothing happens in the app unless the user enters an equation. So the integration principle may be satisfied, but not in the sequence strongly implied by the framework. Value is expressed here for intrinsic motivation as the driver of learning, for basic visual aesthetics in layout, typeface, icons, and color and for the cognitive support represented by decomposition and explanation of component skills.

Interaction Criticism Analysis

This app is focused on in-context use to aid in mathematics learning. From the designer's perspective, this app claims to teachers that its use will "[r]einforce concepts learned in the classroom" and "[a]ccelerate individual learning," thus positioning the app as a tool to build mathematics knowledge outside of the classroom

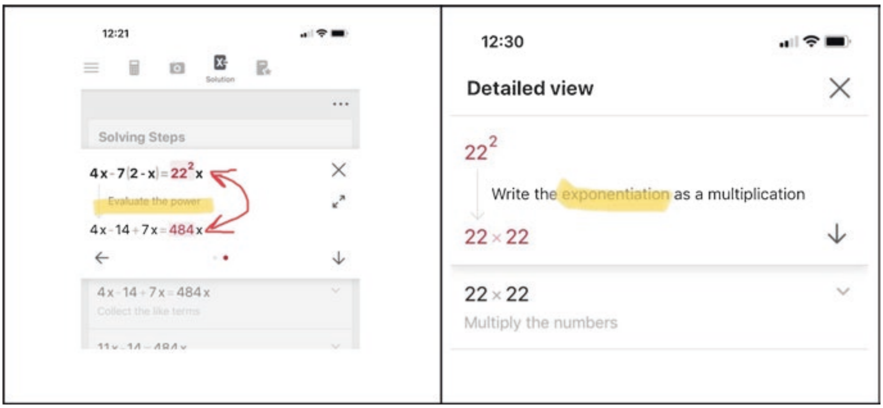

Fig. 4 Portion of a solved equation in which a term, "evaluate the power," is used to label an action, on the left, which may then be decomposed into component skills through the "Detailed view" shown on the right. Highlighting and arrows superimposed by the author

and in the context of specific mathematics challenges. The designer provides an origin story for the app on the website, revealing that the app was derived from specific challenges that the designer had experienced: “out of Damir’s personal frustration, Photomath was born.” This authorial perspective implicitly names a gap in formal mathematics instruction and potentially a gap in the app marketplace for such a tool as well.

From a user perspective, there are multiple audiences (or stakeholders) mentioned in the promotional materials for the app. The primary end user is clearly a student—likely one that is struggling with mathematical concepts. However, the website is also explicitly oriented toward other stakeholders, with clearly named sections demonstrating the apps’ utility for teachers and parents. This range of stakeholders and explicit marketing messaging also reveals potential elements of the social context that may be salient, including the ubiquity of digital devices within the target student age range (at least for students of a certain socioeconomic status), the felt need for personalized instruction, and the social expectation (linked to standardized testing) that students gain a baseline of mathematics ability.

These designer and user perspectives appear to be supported by decisions that are salient within the interface (Fig. 5). Upon first launch, the app provides an onboarding sequence that tells the user they can “scan math problems for instant results” and “learn with step-by-step instructions.” This framing of the app functionality

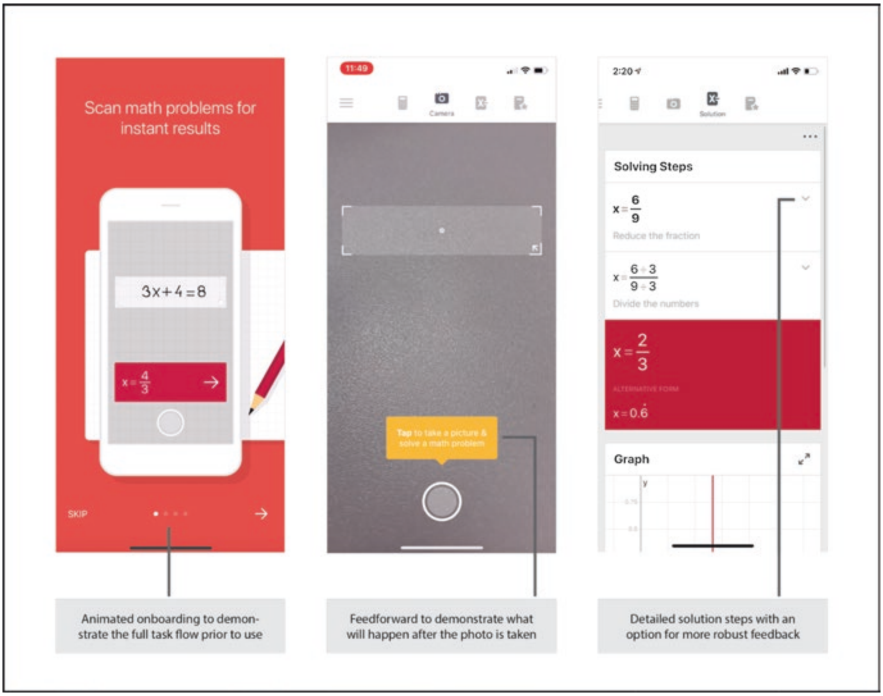

Fig. 5 Annotated screens from the *Photomath* app

directly links to two of the main tabs at the top of the screen: (1) a camera to photograph a math equation and (2) a solution tab to show how the equation can be solved, step by step. This sequence of problem to solution is also supported by feedforward in the app, such as the tip above the camera shutter: "tap to take a picture and solve a math problem." This sequence appears to position the app as a computational support for everyday engagement in mathematics, allowing the user access to visualizations, solutions, and step-by-step instructions on how the solution can be reached.

From a user experience perspective, *Photomath* offers a visually pleasing computational support tool with clear interactions that are supported by onboarding. While some step-by-step instruction uses language that requires formal mathematics education, the amount of detail provided through paged support appears adequate for the app's mediating role among student, teacher, and parent stakeholders.

Perspectives and Value Propositions

In this discussion we place our focus on the results of the analysis and not on the artifacts that were analyzed. What did our analysis bring to light regarding the values inherent in the frameworks from these two domains of design?

The Artifact as Center of Design

An obvious overlap between these apps is the clear instructional perspective manifest in both, a perspective which is addressed in both frameworks of analysis; first principles focus on features—present or missing—aimed at supporting learning, whereas interaction criticism highlights the cues and affordances that signal, or do not, the intended use of the apps, including their potential role in learning. (Interestingly, the UX framework throws emphasis on *learning the app* as an important component of learning overall.) While one framework foregrounds the quality of learning and the other foregrounds quality of interaction, neither framework appears to emphasize individual characteristics or experiences of users or learners. The value position in both places the *artifact* at the center of designing, while acknowledging that quality of learning on the one hand and quality of interaction on the other are the ultimate goals of design.

Interaction criticism foregrounds issues relating to the social context of use, which raises broader performance issues (e.g., lack of adequate formal instruction, access to digital devices for enrichment), not all of which are learning problems or addressed through the application of instructional principles. This framework also promotes consideration of how the learning context may intersect with, and supply aspects of, the instruction. Instructional design practice certainly stresses context analysis, but the presentation of first principles does not provide explicitly for integration of the results into the instruction.

First principles highlight what will be supplied to and requested of a learner as the core considerations in designing. Using the framework for analysis does not result in raising questions that point to the experiential quality of learning or factors external to the artifact that might impinge on its intended support for outcomes. As a framework, first principles promote observation regarding which principles appear to have been followed but do not account for, as an example, the resourcefulness of a learner not provided with everything required by the framework.

While it might seem that a mutual value for emphasis on the artifact would be a point of intersection between domains of designing, we see here that the *center* is assumed to be in different places, at least within these two frameworks. It can be profoundly confounding to effective communication when designers from different domains foreground the artifact and assume this gives them a mutual perspective—particularly when the different centers of value exist in tension to one another. Consider the difficulties inherent in balancing the perspective that "most principles have been provided for" within an experience and the perspective that "the experience is fragmented and difficult to navigate."

Vocabularies of Design

The vocabularies of these frameworks or perspectives are different (e.g., *whole task*, *activation*, and *integration* for ID; *task flow*, *microinteraction*, and *feedforward* in UX). These are not just a different set of words; they point to different foci and fundamentally, we argue, to different values. Perhaps obviously, the ID terms address the instructional support required on behalf of learner/users, while the UX terms address the support of user/learners' actions required to benefit from the instruction on artifact, interaction, and sociocultural levels. In practice, placing primary value in either of these foci will call into question the design moves to be made in service to the other. As an example, the consistency of interactions which surfaced in the analysis of two apps might be considered a secondary concern for designers placing greater value—and attention—on instructional strategies. Those strategies might seem beside the point to a designer who anticipates that the interactions required to access them will be confusing, frustrating, or demotivating. When the vocabularies of designing remain foreign across domains and the values they signal are left unacknowledged, the subtext of design talk between individuals or teams cannot move to a productive middle space between them.

Conclusion

It is difficult to approach the topic of values in design because the values in play will inevitably require foregrounding one type of focus and outcomes over another. Significant effort is required to engage in such value trade-offs and more still to determine how basic values from one field of practice might intersect with those of another in such a way that neither is sacrificed. When values clash, core judgments—fundamental beliefs about the role of design in the world—are called into play, moving designers from a rational place where they are trying to reconcile, say, two terms for the same idea, to a place where both are forced to imagine what design would look like if aspects other than those they have implicitly and explicitly privileged before are now open to questions regarding their relative importance.

In two fields of design practice like instructional design and user experience design, which are closely aligned and which some aspire to reconfigure as learner experience (LX) design (Kilgore, 2016), the work of examining our perspectives and values, and their epistemological assumptions, will have to be done—either haphazardly through individual projects or, preferably, consciously and as a matter of shared scholarship. Through the small window of the analysis we have carried out, we argue that this work is not going to be easy. We would like to consider the creation of a "new space" in communication where we might begin even with simple exercises like the one presented here, carried out in real time and with full consciousness of the goal—not to supplant one vocabulary or set of values with another or to merge into either a useless compromise or a lopsided perspective in which the oldest, the newest, the most- or least-entrenched view predominates—or begin examining value positions in order, ultimately, to enrich them and explore how they may be recast.

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Educational Software Design in Practice: Understanding the Power of Intersecting Disciplines on Design Process

Mohan Yang, Iryna Ashby, Brantly McCord, Tadd Farmer, Umair Sarwar, and Marisa Exter

Educational software design requires an interdisciplinary approach combining theories of learning and engagement, accessibility, and design (Tchounikine, 2011). It envisions collaboration of professionals with diverse backgrounds, including instructional design (ID), user experience design (UX), and software design/development (SD). While these specialists are steeped in disciplinary perspectives, theories, terminology, and processes (Exter & Ashby, 2018; Tchounikine, 2011), educational programs do not necessarily prepare them to understand what other specialists do and how they do it.

Learning in an interdisciplinary environment exposes students to "different kinds of knowing" (Davies & Devlin, 2010), but efforts to embed interdisciplinarity in traditional higher education have often been challenging due to siloed nature of many programs, differences in disciplinary and departmental cultures and terminology, and inflexible curriculum (Gillis et al., 2017; Jones, 2009). This chapter focuses on the experiences of graduate students in one interdisciplinary graduate course. We will examine the impacts of our unique disciplinary backgrounds and interdisciplinary course experiences on our thoughts about design and design process. This is a later incarnation of the course described by instructor Marisa Exter and an earlier group of students (Exter et al., 2018).

To tell our story, we use an evocative, collaborative autoethnography approach where authors are "simultaneously the instrument and the data source," in order to capture the meanings of the collected personal experience (Chang, Ngunjiri, & Hernandez, 2012, p. 22). We co-created discussion and writing prompts to which we each responded; then a core group (first, second, and last authors) synthesized and reflected upon each of our stories, while the rest of the authors reviewed the

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stories for accurate representations of their experience and voices, after which the second and last authors engaged in significant course redesign in response to understandings gained from this study (see Fig. 1). Reflexivity was built into the whole process: from dialogic conversations to the narrative write-up. We each recognized our positionalities within the process and with each other and worked on maintaining an open dialogue (Anderson, 2006; Palaganas, Sanchez, Molintas, & Caricativo, 2017).

Instructor's Story on Course Design: Marisa Exter

Background

The educational software design course (ESDc) was inspired by my academic, professional, and research background. I hold a computer science BS and an ID-related PhD. I have participated in and led teams including IDs, software developers, UX designers, and graphic designers. My research on competencies needed by SDs and IDs highlights the importance of "professional skills" and the ability to work on a team of diverse specialists.

Reflecting on my own educational experience, I recall little scaffolding to help bridge what was learned across liberal arts disciplines and no attempt at crossing or synthesizing across professional domains. Most of my research participants indicated a similar lack of experience with either content or students from different disciplinary backgrounds.

Course Goals and Design Considerations

ESDc aims to help students build understanding, respect, and the ability to create a working relationship across disciplinary specialists, by exposing graduate students to the terminology, techniques, and processes used across disciplines.

The course is structured around a real-world semester-long project requested by a client (such as a faculty or staff member). A "flipped classroom" model dedicates a significant class time to studio time and critique, while application of

Fig. 1 Study process

readings and individual skills are demonstrated through online discussion. In-class activities guide students to apply skills developed in weekly discussions to their team project. Project work is structured through 3–4-week rounds of draft deliverables and documentation and response to peer, instructor, and client critique (See Fig. 2).

Encouraging Reflection on Design Process and Process Models

One thing I hoped this course would achieve was providing students a deeper understanding of design process and the benefits and drawbacks of rigid use of disciplinary process models. In prior years, a few individual students gained the level of insight I was hoping to achieve, but many did not. The types of insights I would like to encourage included:

1. Similarities across disciplinary process models.
2. Overlap in purpose and timing of steps—one model does **not** necessarily fit within another (e.g., ID's development step containing all SD or UX analysis/design/development/testing).
3. Different terms for similar activities; similar terms for different activities (e.g., testing learning vs usability vs underlying software quality).
4. Impact of disciplinary culture (e.g., analysis vs empathy).

Furthermore, in previous years students resisted analysis activities and became solution-focused early in the semester, which I believed could be addressed through fostering a more iterative process.

This year, I hoped to encourage these insights and behaviors through what I envisioned as an iterative yet flexible course design (see Fig. 2); use of design drafts and encouragement to "negotiate" deadlines with me; midsemester online discussion about process models and development of team process models; and purposeful use of critique to send students "back" to analysis or ideation when appropriate.

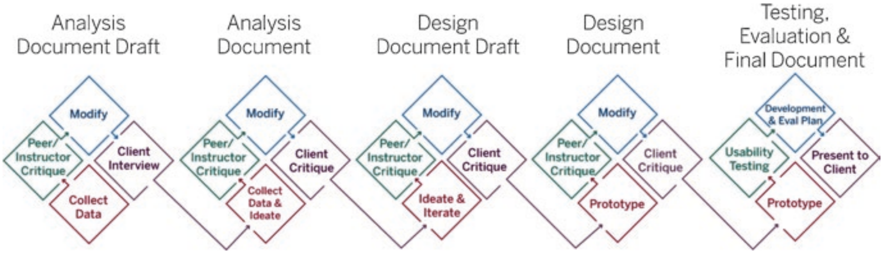

Fig. 2 Course design

Student Designers' Stories in ESDc

As student designers and coauthors, we each individually and collectively reflected on our course experience.

Brantly McCord, Graphic and Game Designer

Current Status
Game Development Education in CGT
MS Student

Educational Background
BS: Video Game Development in
Computer Graphics Technology (CGT)

Professional Design Experience
Graphic design, print, and video game design;
design and delivering of instructional content
for video game development

Understanding of Process Prior to Class My experiences in a variety of fields led me to believe that the design process was input-output: A tech-based problem deserved an iterative design process model. I could see the overlap between models like Agile and ADDIE, but I hadn't challenged the idea that those process models and their environmental effectiveness were suggestive, not strict. I expected that enough people had used those process models in those contexts that it was just decided that was the best way to do it.

Entering this course, I felt as if I was already prepared for whatever could be thrown at me. I would enforce an iterative design process that had worked for similar courses in the past, simply going through the motions. When I read the documentation on ADDIE as a process model, it seemed, at first glance, to be an iterative design minus iteration, which confirmed my suspicions that I was going to rely on old methods. It's safe to say that this didn't happen and that my initial perception was misguided and later updated.

Impact of Class Structure on Project Process The course was designed across a linear ADDIE structure, with an upfront note from the instructors that teams could flex the structure of the class independently if it didn't fit the project. As someone who wasn't exposed to ADDIE before, I'm glad I experienced it in this class: I feel as though resting on an Agile or iterative workflow would've launched us into the work without enough proper analysis, leaving the project without a strong enough foundation.

Since out-of-class assignments were designed based on the linear ADDIE format (understandably), deviation was something we were hesitant about. However, I started feeling that ADDIE was too rigid. I saw our project moving effectively in a non-ADDIE direction, even though we were close to the structure. And so, the light bulb started to flicker on dimly.

Critique from the peers, instructors, and clients, combined with personas and user-focused activities, made us far more prone to catching late-stage mistakes that we never could have caught at the beginning. Our team walked away from every single critique with a new focus on our project, in a good way. Whenever we felt like we were settling in an idea, we'd receive new insight that we couldn't have anticipated on our own, thanks to our interdisciplinary class members. The engineers of the class, for instance, would be confused by storyboards that made plenty of sense to UX designers, and in that intersection, everyone was able to expand their perspectives.

Current Perception of Design Process Design process is the flexible methodology that guides a project through tried-and-true stages of development, often synthesized from both personal experience and process models. The design process exists at many levels, such as top-level overarching process models sourced from a contextual discipline to the emotional delivery of a given task—it is personally and interpersonally biased, and therefore can be shaped to many situations.

Takeaways from Class Experience I was happy to discover after the course was finished that the other teams had found value in diverging from the suggested process in a dynamic way as well. Process models were a robust compass for us when we were lost but did not have to dictate our project. I realized I had been thinking in a limited mindset, believing process models were just meant to be followed. Rather, you use process models as a way to synthesize an effective workflow for your context.

As a game design/development instructor, I've cemented my belief that interdisciplinary experiences allow a project to thrive. In the past, I've taught students to design games from outside the bubble of "video game design" itself ("How does an architect make a building easy to navigate?"), but now I further understand how participating in processes from another field can improve one's range of sensibilities. Things like functional requirements from software development are now something I introduce to my students, which may not have fit into their Agile mindset before; I embrace the idea that solutions are out there, beyond disciplinary boundaries.

Mohan Yang, Instructional Designer

CURRENT STATUS
Learning Design and Technology (LDT)
PhD Student

EDUCATIONAL BACKGROUND
BS: Teaching Chinese as a Foreign Language
MA: Secondary Educational and Teaching
MS: Learning, Design and Technology

PROFESSIONAL DESIGN EXPERIENCE
Instructional designer
Area of design: k-12, higher ed, and MOOC programs
Formats: workshops, e-learning modules

Understanding of Process Prior to the Class Coming from the field of ID, I viewed design process as rigid, but I could see the flexibility in experts' design work. However, as a novice designer, I've been taught to follow linear processes (e.g., the well-known ADDIE model). I personally liked the idea of following a prescribed model to guide my design practice in that I was able to focus on the tasks with a holistic view of my design process. It is easier to get started on a project with a clear path/framework to follow especially for those with minimum design experience. I was not sure about design in other disciplines but thought that it should be similar in terms of the underlying principles. Entering this class, I was curious and hopeful to get design insights from those different disciplines.

Impact of Class Structure on Project Process I had mixed feelings about how the class was structured. At first, I thought it was really sequential, following a traditional ID approach from analysis, design, development, and implementation to evaluation. I sometimes had the feeling of being stuck at one stage as we were not able to move forward due to assignment deadlines. One reason was because of the heavy workload for each stage. I also felt I had to follow the weekly plans to do the "right" thing. However, once we completed the analysis of our project, we had more opportunities for iterations. Such a back-and-forth process was derived from not only the interdisciplinary conversations between my partner and me but also the insights my peers and the instructors provided during group critiques. However, there were elements that distracted us from our design work, such as the tremendous reading load, constant class reports, some unexpected comments from group critiques occasionally, and the lack of freedom on specific design tasks while the uniquenesses of individual process were neglected (none of the projects were related but we had to follow the same process). Overall, my team's design process was a negotiation among the interdisciplinary collision, the class structure, the client requirements, and the instructor's scaffolding.

Current Perception of Design Process My perception has been evolving since I embarked on this journey. In the beginning, I believed design was like an art—designers create things from scratch using individual creativity. Slowly after foundational courses and this design course, I realized that it is more like a scientific approach toward a final goal regardless of the specific methods one chooses, which might include either a rigid or flexible process. Such a goal-oriented activity is usually conducted in a collaborative team where many aspects of design should be considered to deliver a satisfactory product, given the diverse perspectives and backgrounds of the stakeholders involved. Underlying principles of design are similar across different disciplines, but these differences (including different language we speak) should be understood first. Ideally, considerations of different team members should be infused into a process in a way that works best for the target project.

Takeaways from Class Experience What was learned from ESDc deepened my design thinking by not just providing more possibilities in design but changing my design mindset. I brought such takeaways to my internship, where I experienced what teamwork looked like, and talked to people on different design teams. Not every instructional designer came to this field with formal training in ID; almost half of the people I met had different backgrounds, such as marketing, sales, and UX. The experience of this class, especially the embedded design elements coming from outside the field of ID and the collaborative experience with peers from other disciplines, prepared me for industry work. People approach the same task differently, and it will limit me within a box if I only immerse myself in ID without being open to any other voices. This class and my internship experience inspired me to take additional coursework in UX. After all, ID is and should be an interdisciplinary field, so that the designed solutions could meet learners' diverse needs.

Tadd Farmer, Instructional Designer

Current Status
Learning Design and Technology (LDT)
PhD Student

Educational Background
BS: Social Science Teaching
MS: Learning, Design and Technology

Professional Design Experience
Instructional designer
Area of design: k-12, higher ed
Formats: online courses, e-learning modules

Understanding of Process Prior to Class My background in instructional design exposed me to more linear, classical models that are common in ID programs. As a designer, most of my experience came as a teacher in a K-12 environment, so my design process followed practices common in that field: creating objectives from course standards and aligning assessments and activities with those objectives.

Prior to the course, I engaged in a research project involving rapid prototyping and I immediately began to see the benefits of that model of design. I began to incorporate the flexibility and user-centeredness embedded in that model into my identity as a designer.

Impact of Class Structure on Project Process We never really followed the process model we proposed midsemester because the structure of the course became our process. The idea for our project was already pretty well-developed. We had a client that already had a product in place and our job was to improve upon it. We felt our design process should have quickly progressed through the earlier stages of typical design (e.g., analysis). It was common for us to leave a team meeting or a meeting with the client with a clear vision of what the next steps for our design should be. However, when faced with the requirements for the course, we often had to slam on the brakes and return to the analysis stages to fulfill the course assignments. At the end of the course, I felt like we could've given our client a product that was more complete and well-developed if we were able to progress with a little more freedom and flexibility.

I'm always a fan of feedback because I think that it breaks you out of your own limited perspective to see your product or design from the perspective of others. Peer feedback provided us with additional ideas to improve the product and pointed us to resources that may help in our process. However, it became a laborious task to document and respond to each specific piece of peer feedback we received as part of the course assignments.

Current Perception of Design Process A design process is the steps and procedures used to create something of value or worth, including identifying an issue or problem that could be addressed by a potential design, identifying and gathering relevant information (about the problem, people, or possible solution/prototype), conceptualizing and designing a possible solution, and balancing and managing the associate workload and available resources. This process can be explicitly created and followed, or it could be internal to the individual or group and proceed innately.

Takeaways from Class Experience We developed our own process model, which was kind of an eclectic combination of different things, but we never really followed our model. Because of the external factors (e.g., the structures of course), we had to pull back a little bit to revisit some analysis things which weren't necessarily bad but did impact how we were able to implement the process model that we designed. The reality is that design models are never really implemented in a true, faithful fashion. In academia or a workplace setting, there are always going to be other factors out of your control that will influence how well that process model can be implemented.

I think it's important to use a process that is flexible and open to change. There are so many factors that come up during that process and holding true to a process model may not only be impractical but may ultimately impact the success of the design. I also think that having an interdisciplinary team is helpful in designing a process model because many of our projects are interdisciplinary in nature and we need to have tools and processes that match the character of what we design.

Umair Sarwar, Design Engineer

Current Status
Mechanical Engineering (ME)
PhD Student

Educational Background
BS: Mechanical Engineering
MS: Mechanical Engineering

Professional Design Experience
Production design; engineering education design; considerations for emphatic design; product evaluation; teaching undergraduate design courses

Understanding of Process Prior to Class When I entered the class, no such thing as "design process" existed in my vocabulary. The term used in engineering is called "design methodology." The biggest impact that my own educational background had on design process was that iteration and design go hand in hand. You should always be open to iterating within different stages of the process, but once you cross to the next stage, you never go back. Different methodologies focus on different things. Each design process is dominated by the type of product you are designing and who you are designing it for. For example, for an airplane industry, standards are much tighter, so a lot of effort goes into determining the right target values as compared to determining a product for an arthritis patient where your customer needs are more important.

Impact of Class Structure on Project Process The class structure gave us guidance by equipping us with the tools. The flexibly enforced deadlines really helped guide the design process from the outside but inside the team; it was moldable as needed to include personal elements related to the projects. Classroom critique was a useful tool in the design process as I could explain and talk it out with the teaching staff. The critique was targeted toward the elements inside the design process rather than the process itself. That was, particularly, because of the nature of our project. Nine weeks in, our team was still not sure what we were really doing due to the conflict of interest between the client, our team, and elements of the class. If anything, we received a really positive critique on the process model that I had developed, which was designed so that we can adjust it accordingly to the nature of our project and iterate in multiple phases to account for the ever-changing project goal.

Current Perception of Design Process Coming from an engineering background focused toward product design, my idea of the design process has the word iteration written all over it. If there is one thing that we follow in our design process, that is iteration, and there is no fixed pattern. So, my definition of the design process is, from the engineering field, be open to iterate and use any tools you deem necessary and seem appropriate according to the type of product.

Takeaways from Class Experience My teaching style has been impacted greatly by this class, including the introduction of scenarios in personas and using a modified design process, including iteration among phases. In engineering, typically iteration is done in a single phase. For example, if you are in the drawing phase, you assume everything done in earlier phases is correct, and iteration is only needed within this phase. The phases are not interconnected. Now I urge my students to keep living documents in Google Docs rather than in a notebook they can't change. Even if, 7 weeks into the assignment, a student feels that they were overly optimistic with a constraint and are having trouble working with it, I work with them to change those living documents and iterate in the previous phase rather than forcing a design to fit the constraint.

Synthesis and Reflection

We (students) reflected on our individual reflections through reviewing and commenting on each other's stories to help each other develop our thoughts and gain insights into our own experiences, as well as to add clarifications and richness. Then a core group (first two authors) reviewed each story and identified several themes that were core to our group experience (discussed below). Each author had the opportunity to review and provide additional thoughts.

Shifting Understanding of Design Process

Entering the class, our understanding of design process was based on the way we were trained, and we spoke design languages unique to our own disciplines. As part of the interdisciplinary nature of ESDc, we had the opportunity to be exposed to, explore, and synthesize signature process models from multiple fields, as an effort to best fit the design and development process for each team. By the end of the course, we developed a shared appreciation for characteristics of design processes that were not common to some disciplinary process models, including flexibility, iteration, goal orientation, and adaptivity to the needs of particular problems.

Constraints Imposed on Design Process by the Course Structure

Although teams had some level of freedom in approaching design methods and specifications, the need to submit drafts, reports, and discussions in a specific order and by a specific due date greatly impacted our team design process. Therefore, even though a midsemester discussion prompt asked us to develop a unique process model for our teams, these were not really followed. The actual design processes were derived from the negotiation among individual team members based on the introduced process models, readings, class discussions, and performance evaluations. Group critiques shaped the look of our design artifacts at different stages and even shifted our process at some points, by providing not only suggestions on our approaches and design elements but also new insights which stimulated outside-the-box thinking, especially after we had immersed ourselves in the projects for so long.

Tension Throughout the Design Process

Our stories revealed design tension between teams and the instructors, when teams had to approach specific tasks in a perceived linear way. Now, looking back at our experiences, a perceived power dynamic of an instructor-student relationship (i.e., students are the ones *being* taught) might have contributed to some of these frustrations. For example, coming from different disciplines, we might have had different ideas regarding specific tasks or acceptable design shortcuts, yet we felt obligated to follow the instructor's lead and accept the feedback. As a result, we might not have been comfortable with the negotiations that are often the norms for a design environment.

Instructor Response and Reflection

During and after the semester, I experienced some frustration about students' responses and mismatch between what I expected and what students got out of the course, particularly in the area of design process. Students' responses to reflection assignments during the semester indicated that they valued elements of design processes they were exposed to, particularly the value of iteration and flexibility. They also particularly appreciated techniques they were asked to use, such as personas, scenarios, and usability testing.

While designing the course, I recognized that there was a design tension between ensuring that students fully engaged in each aspect of the process and my desire for them to follow their own process. My attempt to offer flexibility through the use of multiple drafts and my openness to negotiation about due dates fell flat; students resented the perceived workload and did not "negotiate" unless I firmly suggested they move a deadline based on my understanding of their constraints. Furthermore, critique comments that were intended to encourage them to iterate by gathering additional primary and secondary data or pushing them to further ideation were seen as impeding progress. In individual teams, I felt that these behaviors and attitudes were based on issues with clients or the team's solution-focused attitudes.

Working on this chapter with students helped me understand *why* the course design did not function as I intended. As discussed by students in the previous section, students perceived the course design as a linear model, enforced by assignment deliverables (Fig. 3). My coauthors' reflection helped me realize that the power dynamic between instructors and students meant students were not able to push back against my set deadlines for specific deliverables or understand what I meant when I encouraged them to "negotiate." While they felt they had to respond to my critique, it was more likely to cause confusion or feeling that they had not met my criteria, rather than being seen as a natural part of an iterative process. Finally, my desire to scaffold behaviors such as reflection on critique led to the need to submit deliverables nearly every week, which overwhelmed the students. Clearly, I needed to take a step back and look again at the course design.

Course Redesign

Over the summer, Marisa Exter and Iryna Ashby (teaching assistant and LDT PhD student) engaged in their own course redesign process, using many of the design tools and techniques they taught in the ESDc. The result is a course design that provides multiple experiences with a full design process through the use of four sprints (Fig. 4). Scaffolding is intended to fade across the semester to help students build confidence and competence by the end of the semester. This design is being piloted in fall 2019.

On the first day of class, students participate in a 2-hour warm-up sprint on an instructor-provided project, reading some preselected literature, engaging in empathy-building techniques, setting a problem statement, ideating on design ideas, and creating a paper prototype for usability testing with their peers. All activities are highly scaffolded through the use of a workbook and continuous engagement with the instructors. In the second week, students review project briefs created by clients and participate in a Q&A session. Students then select their projects and form teams. As teams, they start sprint 1 using the same materials as in the warm-up sprint. For weeks 3–5, students engage in a 3-week sprint (sprint 2). While there is no workbook, the instructors facilitate activities throughout the 3 weeks and provide a report template. Finally, the remainder of the semester is spent on sprint 3, for which students propose their own design process model and timeline of deliverables. Rather than creating separate analysis, design, and test documents as in the past, all are combined into one document, which can be completed in increments.

The "flipped classroom" model is retained. Detailed discussion prompts provide scaffolding, requiring students to engage deeply with readings, connect with

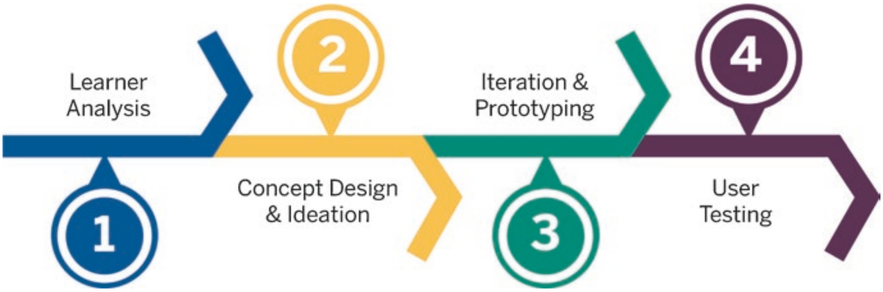

Fig. 3 Students' perception of course design

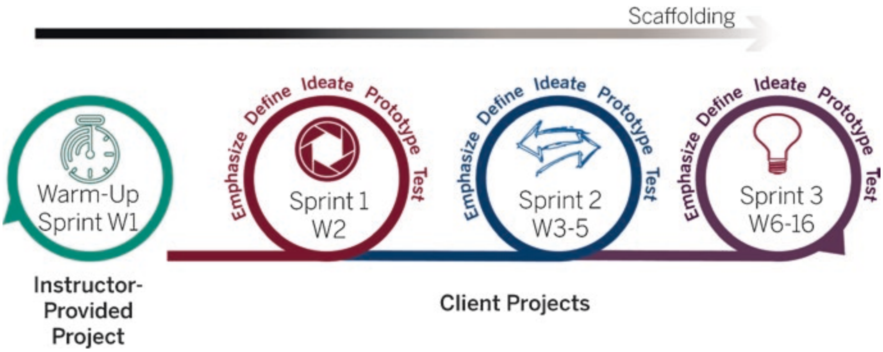

Fig. 4 Course redesign: four sprints across two projects

personal/disciplinary experience, apply what they have learned to an aspect of their project, and reflect. Although topics are spread throughout the semester, foundational readings (which include short videos and practical resources) are provided during the first 5 weeks to enable them to engage in each part of the design process.

Conclusion

Intersecting multiple disciplines empower students to reflect on their design process for desired design outcomes. If we want students to be creative, flexible, and engage in an authentic interdisciplinary experience, we have to ensure that students have the knowledge, skills, and tools needed to have the competence to design their own process. Only through meaningfully engaging with students, through in-depth reflections on individual experience, are we able to iterate on the course design in a way that meets diverse needs of interdisciplinary students.

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Unifying Material Culture and Traditional Research: How Academic Museums Stimulate Interdisciplinary Experiences for Faculty

Caren S. Oberg and Lin Nelson-Mayson

Introduction

Taking students on a museum visit is a rather familiar, almost ordinary, form of instructional method. Most of us can remember going on such field trips when we were in school. Armed with clipboards and treasure hunts, we were encouraged to use the paintings, stone tools, and costumes – some of the objects that make up the material of a culture (material culture) – to find out more about art, science, or history than we may encounter in the classroom. In designing learning experiences, it is common to use museum exhibitions as learning texts. Museum professionals have even adopted this language in referring to their visitors as learners. The field of museum education developed from this notion.

Research on the educational impact of exhibitions as learning experiences or products for and on visitors is well documented and ongoing (Allen, 2004; Borun, Chambers, Dritsas, & Johnson, 1997; Cooner, 2011; Falk & Dierking, 1992; Hein, 1998; Perry, 2012). These researchers suggest that learning in exhibitions occur when visitors engage with the materiality of the topics and ideas articulated through the objects. Insights are achieved through studying the material culture resident in the exhibited objects. Importantly, however, this research has always focused strictly on the learner's engagement with the finished exhibition.

In this article, we will describe how academic researchers – curatorial researchers and traditional disciplinary researchers – are themselves learners while they are in the process of developing this very specific type of instruction and the ways in which such experiences are opportunities for authentic interdisciplinary work. Before continuing, several definitions will be useful for readers not familiar with the inner workings of a museum.

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Material Culture Identified by scholars in the mid-1970s, material culture is the study of the materiality of society, as well as a name for the objects which that society produces (Dudley, 2013; Prown, 1982; Woodward, 2016; Yonan, 2011). Leland Ferguson (1977) described material culture as "an ever increasing proliferation of material items. Farm tools, ceramics, houses, furniture, toys, buttons, roads, cities, villages—the list continues almost *ad infinitum* and includes all of the things people make from the physical world" (p. 7). Ferguson's partial list denotes the objects of material culture. Using material culture as a way of understanding the world is the central component of the museum experience.

Curator In a museum setting, curators (from Latin *curare*, to take care of) are the professionals who are responsible for one or more collections of objects. As Lemire (2009) describes, "the physical features [of an object] cannot themselves create a narrative. Stark descriptions of artifacts are not enough. We must venture into analysis and explanation, blending these material forms into the wider current of historical scholarship" (p. 99). Curators are the researchers who "venture into analysis and explanation." Professional curators are practiced scholars who pose questions and find answers to understand human culture at the material level. As Gregg Finley suggested over 40 years ago, they are "particularly sensitive to the complexion and the complexity of the three-dimensional document, [and] rise to the occasion and meet 'the challenge of the artifact'" (Finley, 1984, p. 20). Curators at the University of Minnesota's Goldstein Museum of Design (GMD) draw on research used to understand and shape exhibition development, in particular the Smithsonian Institution's *Guidelines for Accessible Exhibition Design (Smithsonian,* 2010*)* and such seminal works as Beverly Serrell's *Exhibit Labels: An Interpretive Approach (Serrell,* 1994*)*. An early and crucial research text used by GMD is *The Visitor's Voice: Visitor Studies in the Renaissance-Baroque Galleries of the Cleveland Museum of Art, 1990–1993 (Schloder,* 1993*)*. This study is an influential work in the development of exhibition galleries which support and encourage visitor learning experiences.

Guest Curator There is no official description for guest curators. GMD guest curators are selected for their specialized expertise to co-develop exhibitions with museum staff. They may be University of Minnesota faculty and graduate students, or community experts.

Academic Museum Goldstein Museum of Design (GMD) is an academic museum. What makes an academic museum different from the better known public museums such as your city's art museum or natural history museum? An academic museum is defined by the Association of Academic Museums and Galleries as a place to "preserve our past and stand as vibrant cultural centers for their respective communities. [But] academic museums are the training ground for the next generation of cultural leaders, the first engagement for many of our young with original objects, and campus centers for *interdisciplinary discussion*" (authors' italics) (AAMG). What also sets academic museums apart from other museums is that academic museums are settings for informal learning inside institutions of formal learning, generally institutions of higher education. Academic museums can and should regularly prioritize and support faculty research in a way that other museums generally do not. The most common type of academic museum is the art museum, followed by natural history, but some universities are home to more. The University of Minnesota hosts several types, covering art, natural history, living collections (botanical gardens, plant conservatory, birds), history, and – uniquely – design. The GMD is named in honor of UMN professors Harriet and Vetta Goldstein whose textbook *Art in Every Day Life* (1925) sold nearly 250,000 copies for use in classrooms across the country. Influenced by the instructional concepts of Frank Parsons (Parsons School of Design) and Arthur Dow (Teachers College of Columbia University), the Goldstein sisters developed a new, accessible vision of design and helped launch the Midwest as a design powerhouse. GMD cultivates object-based teaching, scholarship, and inspiration for students, faculty, and researchers. Such research and scholarship generally begin with direct engagement with objects from the collection of over 34,000 objects, each of which conceptualizes a component of design. Relevant to this discussion, the GMD develops exhibitions with faculty guest curators that encourage interdisciplinary educational experiences by imbuing their exhibitions with a range of interpretive foci grounded in material culture.

Exhibitions as Interdisciplinary Learning Design for Faculty

We contend that the very study of objects fosters interdisciplinary understanding. For example, studying woven cloth may include agriculture and climate (fiber source), chemistry (dye processes), technology (loom and weaving techniques), cultural history (surface design and use), and human factors (shaped cloth, if used as apparel). Given that the study of objects fosters interdisciplinary understanding, it follows suit that developing exhibitions does as well.

Holley (2009) considered interdisciplinary education as a way to denote the "degree of integration between various disciplines of knowledge" (p. 4). More critical to the research presented here is her definition that "interdisciplinary education typically (although not always) uses the collaborative engagement of researchers from multiple fields," and that this is different from cross-interdisciplinary work (2009, p. 4). While the work on interdisciplinarity has focused on discussions between and among academic disciplines, the same work overlooks the academic museum for its fundamental purpose as a site of interdisciplinary work. Holley's distinction is vital as exhibitions, especially those in art and social sciences, may often seem interdisciplinary when they are, in fact, cross-disciplinary. In this article, we propose that not only are academic museums places of interdisciplinary content and learning but that the creation of exhibitions is most robust when curatorial research and exhibition development is, itself, interdisciplinary. The construction of the interdisciplinary exhibition is a collaborative activity in itself which enables multiple academic disciplines to produce and present new research. Lastly, the process of exhibition development uses the same developmental strategies as other areas of instructional design, including a basis in learning theories, problem framing, and generating ideas to result in the development of an instructional activity.

As design itself is interdisciplinary, interdisciplinarity, the study of the methods and theories of interdisciplinary approaches to learning ("What is interdisciplinarity?" 2019), is an embedded element of the very fabric of GMD's work. If GMD exhibitions are not interdisciplinary, then the topic is not being fully engaged by GMD staff or guest curators. In addition to design fields, topics have included innovation and creativity, prototyping, the impact of social change on housing, gerontology, rural issues, security, climate change, sex trafficking, biomimicry, sustainability, and others. GMD exhibitions as wide-ranging as 2010's *How Secretaries Changed the Twentieth-Century Office: Design, Image, and Culture* and the 2015 exhibition *America's Monsters, Superheroes and Villains* picked up on several of these topics.

GMD and Guest Curator Process

GMD presents six exhibitions per calendar year, three of which are object based and three which are panel only. GMD supplies a relatively short, 2–3-page application which asks the prospective curator to outline their exhibition concept and provide examples of content. College of Design faculty are encouraged to submit exhibition proposals, and proposals are also accepted from academics and non-academics outside of the College. Often GMD hears about specific research and reaches out to the faculty member to encourage them to submit a proposal. Proposals are reviewed by GMD staff on a rolling basis. Once a proposal is accepted to be developed as an exhibition, GMD staff and the faculty member, now referred to as the guest curator, start to meet to engage both parties in big picture thinking of the content and design of the exhibition. This is a true collaborative effort as the guest curator begins to consider how to communicate their research to students who are not in their field as well as the general public. GMD staff begin to consider the depth and reasons of the faculty's research and how to communicate this knowledge using objects and exhibition learning research. Through about 9–12 months of weekly or bimonthly meetings, the exhibition evolves.

Although GMD did not have professional formal learning goals for guest curators, it has operated with a set of informal goals for the guest curator model. However, through the development of this research project, several defined learning goals have emerged that will serve to formally articulate the expectations of that model. At the end of the exhibition process, GMD guest curators will be able to speak to an awareness of:

- Museum exhibitions as a communication method
- Learning theories and scholarly research behind exhibition development
- Ways in which GMD supports their research

- Objects as complementary methods to explore and explain their research

As an authentic interdisciplinary experience, there are also learning goals for GMD staff. Staff will be able to speak to an awareness of:

- Current research being conducted by faculty in the College of Design – an important impact as the University of Minnesota is a Research One university
- Ways in which GMD can support faculty research
- New fields of research which can influence exhibitions in the future

Outcome of Process and Learning Design

This article focuses on the exhibition process for GMD guest curators, specifically the responses of two past guest curators.

Guest curator A is a Professor in the Housing Studies Program in the Department of Design, Housing, and Apparel at the University of Minnesota. Her expertise is in affordable housing, community development, senior housing, urban neighborhoods, and biographical narratives. Her first exhibition with GMD was *Minnesota Affordable Housing* in 2007. *Minnesota Affordable Housing* was developed to complement a national traveling exhibition on affordable housing. This guest curator was approached by GMD with an offer to develop the exhibition and a symposium on the topic. Her next exhibition, *Minnesota Affordable Housing* was developed as a panel survey of affordable housing projects in and around the state, and the panels were then donated to representatives of the projects for display in their main offices. Her third exhibition, *Smart House, Livable Community, Your Future* (2010) was an ambitious project with products and interior design choices to illustrate solutions for aging in place. Guest curation included a Housing Studies Program graduate student. The unique challenge for the guest curators was to present possible research-based solutions related to aging in place in a manner that encouraged interaction with objects and introduced them in a friendly, homelike environment. The resulting solution was to transform GMD's gallery into a one-bedroom house in a garden setting, complete with a no-step entry, as seen in the *Housing Exhibition Photograph* (GMD, 2010a, 2010b) (see Fig. 1).

Based on her past collaborations with GMD, guest curator A proposed a third more complex exhibition, *Beverley Oliver Hawkins and Nieeta Presley: Influential Saint Paul Developers* (2019), showcasing the work of two African American women who rebuilt an area of St. Paul, MN, to support community housing and economic vitality. This exhibition required more in-depth presentation of content that could be both obscure (financial) and sensitive (resident responses).

Guest curator B is an Associate Professor of the School of Architecture in the College of Design. She teaches architecture and urban history and also holds positions in the Departments of American Studies, Art History, Cultural Studies, and Comparative Literature. Her teaching and scholarship address issues concerning the complex roles that built environments (the physical human-made environments)

Fig. 1 Photograph of completed exhibition *Smart House, Livable Community, Your Future* (2010). Goldstein Museum of Design. Retrieved from http://goldstein.design.umn.edu/exhibitions/previous/xhibit_detail_2011_smart_house.html

play in the production of values, identities, and social relations. This guest curator and her art history graduate student developed the exhibition *How Secretaries Changed the Twentieth-Century Office*: *Design, Image, and Culture*. This 2010 exhibition was designed as an interdisciplinary examination of the office environment through the lens of the secretary. It combined interior design, architecture, product design, technology, fashion, and social history. As seen in the photograph for *How Secretaries Changed the Twentieth-Century Office*: *Design, Image, and Culture* (2010), it was an object-intensive exhibition that introduced the secretary as a transformative force who was essential to successful office functionality yet often the focus of ridicule (see Fig. 2).

Fig. 2 Photograph of completed exhibition *How Secretaries Changed the Twentieth-Century Office*: *Design, Image, and Culture* (2010). Goldstein Museum of Design. Retrieved from http://goldstein.design.umn.edu/exhibitions/previous/xhibit_detail_2010_secretaries.html

Analysis

Guest Curators Investigate Museum Exhibitions as a Communication Method

That museum exhibitions are unique communication methods is one of the key observations of our guest curators. As faculty they are accustomed to presenting their research for two audiences – students through formal classes and their peers through publications. Considering how to present their research for a general audience in an informal learning environment requires a new level of contextualizing. Guest curator A explained: "To be able to curate an exhibition is different than writing it up or teaching it. You reach a different audience so you deliver it differently. It Makes you think about what you want to say and that has changed how I think about what interests me." It is not only that guest curators learn to present research in a different way: they also observe what it is like to see people consume their research in a setting that allows the visitor the freedom to explore based on their own interest. One of our guest curators explained that "It is a different thing to watch someone else experience your research. [Presenting your research as a museum exhibition] is a unique experience we have at the UMN." Being willing to have this experience is a unique attribute of GMD guest curators, as not every faculty member would necessarily be comfortable "watch[ing] someone else experience your research."

Through working with GMD, guest curators are able to situate their focused research in an expanded context. GMD can often suggest ways in which guest curators can add more context to their research to make it even more understandable to students inside and outside their field and to the public. The exhibition *Mixteca Stonecutting Artistry: Sixteenth-Century Ribbed Vaults of Oaxaca, Mexico*, focused on three churches in the Mixteca region of southern Mexico constructed during the sixteenth century with complex late-Gothic ribbed vaults. The churches are San Pedro y San Pablo Teposcolula, Santo Domingo Yanhuitlán, and San Juan Bautista Coixtlahuaca. This exhibition explored the unique connection between Mixtecan master masons and European geometry. Texts and objects featuring stereotomy (the science of cutting solids) and an analysis of solutions used in the vaults' construction that highlighted building techniques.

This exhibition was originally positioned to singularly and deeply discuss stereotomy. The guest curator, a scholar in sixteenth-century Mexican church construction and a UMN architecture professor, focused primarily on the construction materials and techniques of sixteenth-century Mexican stonecutters, including a singular and deep discussion of stereotomy. GMD encouraged him to broaden the exhibition to include the cultural translations and transformations which needed to occur for sixteenth-century New World stonecutters to adapt their traditions to meet European construction demands. As a result of this new context, the guest curator consulted researchers in Mexican cultural history, which was then woven into the exhibition.

GMD Guest Curators Introduced to the Museum Field

Although GMD has included the guest curator model in its exhibition development for over 40 years, GMD is new to research on this practice. We find that guest curators are almost always new to museum content development, exhibition design, and how learning occurs by visitors looking at the finished product. In the research environment of the university, this positions the museum as an active peer rather than a passive site with lesser awareness and engagement in the research experience. Guest curator A acknowledged both the difference museum professionals have and that of her own field, saying "I keep learning from GMD staff as our world views are different in how information can be used by the general public and what kind of impact you [the guest curator] want to have." Guest curator B was more specific in her comments about the processes of exhibition development, saying "I learned a lot about both the broad conceptual process and the detailed work that goes into producing an exhibition." The timing and pace of exhibition development was also of interest to our guest curators, as guest curator A explained, "[The exhibition] is a very different way of thinking than my regular job, which is very segmented and broken into doable pieces based on the semester."

GMD Supports Guest Curator Teaching

As an academic museum, GMD strives to support our faculty's teaching and we strive to support faculty in their student engagement. We have found that guest curators embraced this element of their collaboration with GMD. Guest curator A reflected on how producing exhibitions, specifically *Minnesota Affordable Housing*, allowed her to engage her students in a way which is not often done at the College of Design. She explained that "The students helped me to get ready for the opening. The students helped out as a gift, not as a requirement. They were engaged with the topic. Then they gathered in my office to talk about the work. It was a really special time, with the exhibition was in our midst. The exhibition led to this opportunity." Being a guest curator for a GMD exhibition allowed this guest curator to extend her reach as a teacher and mentor. She was able to model how research and exhibition development function collaboratively, introducing students to another profession (museum studies) and to another outlet to communicate their growing knowledge.

Objects as Complementary Methods to Explore Research

One of the many roles of museums is the study and use of material culture, the objects which humans create and use. GMD has the distinct mission of researching and presenting objects which show the interconnectedness of design. Exhibitions can blend apparel, architecture, decorative arts, graphic design, product design, and interior design. Guest curators bring their deep knowledge of a particular area, but approach the exhibition development process fresh eyes to the research that undergirds museum exhibitions. Through their experience as guest curators, they are able to see larger integrations of content. Guest curator A was quite specific in how GMD and objects supported her research, saying that producing her exhibitions makes you "…think about your topic deeper." Guest curator B described her exhibition experience as one that "…made me all the more aware of the interrelationship between different forms of material culture and space in our designed environments." This guest curator went further to explain that the encouragement of GMD staff and the variety of its 35,000 objects allowed for experimentation in blending objects with research, specifically for *Twentieth Century Office*:

> Another takeaway was a renewed appreciation for the kind of museum the Goldstein is. We weren't locked into a way of presenting objects and ideas that had to conform to a set way of doing things. The Goldstein offered the flexibility to figure out what we needed for this particular exhibition. The result was a collection of objects and ideas that would seldom (if ever) come together in the same exhibition; ranging from early twentieth-century typewriters, clothing, and images to mid-twentieth-century office equipment, clothing, more images, and furniture. A curator from the Museum of Modern Art in New York toured the exhibition and liked the fresh, interdisciplinary approach so much that it was reviewed in a New York-based design magazine.

Conclusion

The academic museum exists in the realm of the university or college landscape, an environment of often distinct pursuits that are encouraged to interact, but for which there is often no clear path to do so. The natural interdisciplinarity of museum exhibitions in this context provides a perfect opportunity for that sharing of information to occur. While the museum visitor is often the focus of this exercise in communication and material culture, curators and organizers are the initial beneficiaries of this experience through the challenge of shaping content within a particular environment to achieve public learning goals. For guest curators, developing a museum exhibition based on their research gives them insight into the museum profession as well as an awareness of the nature of the museum exhibition as a unique, research-based communication method. GMD's history of developing the guest curator model provides an opportunity for faculty researchers to experience their own interdisciplinary learning within the robust environment of the museum exhibition.

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Improving Reading Speed for Dyslexic Readers

Rachel Brotherton, Latifatu Seini, Linlin Li, and Suzanne Ensmann

Introduction

The average reading speed of most adults is around 200 to 250 words per minute, and 300 words per minute for college students (Thomas, 2010). Dyslexia is a reading disability due to problems identifying speech sounds and learning how they decode letters and words. Dyslexia occurs in significant amounts of the population of all ethnic backgrounds. It is a learning disorder that causes difficulties with phonological skills, short-term memory, visuospatial skills, as well as sequencing (Bartlett and Moody, 2010). Dyslexia results in difficulties for students throughout their study and work. Low literacy, which is termed "developmental dyslexia," manifests in significant reading difficulty. Reading requires the acquisition of good orthographic skills for recognizing the visual form of words, which allows one to access their meaning directly (Stein, 2001). Most reading problems have a fundamental sensorimotor cause, such as an impaired development of the visual magnocellular system. In spite of their learning difficulties, children and adults with dyslexia can improve their learning experience through cognitive and developmental psychology (Snowling, 1987). According to Shaywitz and Shaywitz (2003), learning performance of both children and adults has improved with specific intervention therapy and effective management.

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Purpose of Study and Problem Statement

The purpose of this study is to investigate different strategies for improving the reading speed of adult dyslexic readers. "The binocular instability and visual perceptual instability can cause letters to appear to move around and cross over each other" for dyslexic readers (Stein, 2001, p. 15). Hypothetically, experimental designs with increased spacing between letters, such as "L E T T E R S," or transformed appearance of sentences, for example, from horizontal to wavy lines, or smaller print to larger print, would improve reading performance for this audience. The research will also contribute to the field of e-Learning course creation and promote further provision of relevant accessibility to online learners with dyslexic disorders, thus strengthening the general learning outcome of society. Participants will also benefit individually by recognizing their reading speed and understanding what type of materials best enhances their reading abilities.

Research Questions

The research study was initiated by addressing the following questions:

1. Will the rearrangement of letter space be helpful in improving the reading speed of dyslexic adults?
2. What is the difference between larger prints and smaller prints for dyslexic readers during the reading? Is there any difference?
3. Can smaller paragraphs accompanied by illustrations help dyslexic readers advance faster?
4. During the reading process, is there a difference when one eye is blanked, in accordance with testing the hypothesis that blanking one eye will aid dyslexic readers' reading process?
5. Is there a difference in reading speed between reading on paper print and digital devices for dyslexic readers?

With careful review of the literature and instructional design considerations, the research questions were to focus on ways to improve the reading speed of adults with dyslexia.

Literature Review

The latest research shows that the remediation of dyslexia requires changes of high-frequency repetitive transcranial magnetic stimulation High-Frequency repetitive Transcranial Magnetic Stimulation (hfHF-rTMS) over areas that are underactive during reading in dyslexics. In order to improve the reading speed of dyslexic adults, a different visual stimulation is required than that of regular readers. However, the previous research study does not specify what type of specific visual stimulation is required. In this case, can specific instructional design targeting hf-rTMS activities improve the learning outcomes in children and adults with dyslexia? If so, what are those specific instructional design models that content developers can utilize for the creation of learning materials? In what ways are instructional designers keeping up with ADA compliance to create instruction for dyslexic students?

A dyslexic brain's temporoparietal language areas on the two sides are symmetrical without the normal left-sided advantage (Stein, 2001). Brain ectopias (brain warts) are found in the cluster of the left temporoparietal language areas. The visual magnocellular system manages the timing of visual events in reading, which signals visual motion if unintended movements lead to images moving off the retinal slip. The sensitivity to visual motion helps determine how well orthographic skills can develop, and an impaired visual magnocellular system shows reduced motion sensitivity, as in the case of dyslexia. Many dyslexics show unsteady binocular fixation with poor visual localization, particularly showing left neglect. The binocular instability and visual perceptual instability can cause letters to appear to move around and cross over each other. The author also suggests that blanking one eye (monocular occlusion) can improve reading accuracy or speed. Shaywitz's article indicates that functional magnetic resonance imaging (fMRI) provides evidence of the neurobiological signature of dyslexia with disruption of two left hemisphere posterior brain systems, in which both parietotemporal and occipitotemporal systems are impacted. The left occipitotemporal system impacts fluent reading, and remediation can include provision of evidence-based, effective reading intervention. fMRI also indicates that of the two types of dyslexia, one has genetic bases, and the other environmental influences (Shaywitz, 2005). Both can benefit from intervention, precise identification, and effective management.

In this experimental research study, an attempt to provide solutions for the visual cluster issue that might result from the disruption of two left hemispheres was conducted. The motion sensitivity of unsteady binocular fixation which generates poor visual localization was investigated by the use of wider spacing between letters on the reading materials. Reading content was created tailoring to this learning disability and offered to participants for the purpose of examining motion sensitivity and unsteady binocular fixation issue. The hypothesis of this research study is that reducing clutters in reading materials, such as implementing a less complicated font style like sans serif, or increasing spacing between letters and lines, may help dyslexic readers improve their reading speed.

Data Collection Methods

A mixed method approach was used to collect data from dyslexic readers using a variety of platforms, including surveys, individual interviews, questionnaires, observation, and experimentation to quantitatively and qualitatively investigate how instructional content design can help improve dyslexic reading. We designed five experimental reading materials for the participants. Among these methods, participants opting to partake in the study read an excerpt of the same reading in regular typeset with Times New Roman and then repeated the exercise with experimental designs including similar excerpts in San Serif, wavy line sentences, larger font and increased spacing between letters and lines. The experimental reading interview served as a qualitative data collection to probe the details of which experimental design improved the participants' reading speed.

There were a variety of methods used for data collection, in which social media usage, internal networking, and snowball sampling all contributed to the volume and frequency of data gathering. Surveys created in Qualtrics were distributed to a dyslexia support group on Facebook and to the internal network of a learning disability community on the university campus. Neighborhood social networking pages were used as a snowball sampling technique to recruit participants by another participant for the later experimental interview process. Five participants who completed the survey expressed interest in being interviewed. The interview includes reading experimentation that brings descriptive details on how the participants responded to the experimental design.

Data Analysis

The data analysis started with the results reported in the survey. The responses for each question on the survey were represented by a table, pie charts, and bar graphs. The numeric data in the table includes the participant's responses. With the pie chart providing the demographics, each participant's reading speed was self-identified and recorded in the bar graphs.

To generate the final report, responses provided by each participant were recorded and each response was carefully examined to determine any correlation between responses and the conclusion. The responses were compared and reviewed to identify the discrepancies and similarities between participants. The interview process and experimental results generated by each participant were also recorded and compared with the predicted outcome.

Results/Findings

The data gathered from the survey with twenty five participant indicated that 50% of the participating dyslexic readers between the ages of 18 and 75 self-identified with a reading speed of fewer than 200 words per minute. Twenty-two percent of the participants self-identified that they can read 200–300 words per minute while 27% were unsure. Fifty-six percent of the dyslexic readers preferred reading on an electronic device and the rest preferred hard copy. Fifty-five percent of the participants graduated from high school, 33% held an undergraduate degree, while 11% with postgraduate degrees. Among the participants, 29% mentioned that audiobooks or read-along books helped their reading, and 24% mentioned using a ruler to block other lines or following along with their finger to track the words. Nine percent believed nothing is helpful and the rest believed bigger text and highlights, or the degree of interest in a reading material will determine the effectiveness of their reading. When asked what else can help improve their reading speed, one participant who was also diagnosed with ADD believed that cannabis can remove his anxiety while he is reading. There were 71% of the participants who stated that they need a quiet environment to help them concentrate on reading.

The experimental interview with four participants showed that participant A can read approximately 98 words per minute with reading material No. 1, the normal font in Times New Roman; however, this reading is a bit off due to a wrong setting with the timer that causes a potential invalid result. With wavy line sentences in reading material No. 2, the participant can only read 38 words per minute. As the researchers originally predicted, the best and the easiest experimental design for participant A to read was reading material No. 3, with a space between each letter in a word, and the participant scored accurately with 80 words per minute. The second easiest to read material is No. 4, which used Sans-Serif font style, and contained larger font size and bigger spacing between lines, and the participant scored 91 words per minute. Experimental reading material No. 5 scored the lowest which was 40 words per minute, and the reading matieral was rather unconventionally designed with vertical letter arrangement than the horizontal norms. This type of letter arrangement imitated the traditional print of Chinese characters that was read from top to bottom.

For participant B, reading material No. 1 received a score of 98 words per minute; however, the participant read it out loud and did not pay attention to what the passage meant as he read along. When the participant was asked to choose either read out loud or read quietly, whichever method can help him concentrate on meaningful reading, he scored 86 words per minute with quiet reading on wavy line material No. 2 and scored 85 words per minute on reading material No. 3. With a larger font and bigger space reading material No. 4, participant B scored as high as 112 words per minute and 52 words per minute on reading material No. 5.

Participant C performed the experiment virtually and chose to read the materials electronically. They spent 1 minute 47 seconds reading the first material presented. This was their longest elapsed time, but not the most challenging. When asked which chapter they found most challenging, they said it was the last reading material (No. 5) and this was because of the way the letters were arranged. They found reading material No. 3 easiest to read. They said their next easiest material was reading material No. 4. Although they spent the least time reading this (58 seconds), according to them, it was challenging because of the word "SYNTAX," which they did not know the meaning of and slowed them down as they encountered it several times throughout the passage.

Participant D also agreed that reading material No. 4 is their favorite and that it helped them read faster, according to their recorded result. The vertical arrangement of letters was the most difficult text style for them since it was completely unfamiliar.

An overall evaluation of these participants revealed that they all found the experimental design reading material No. 3 the easiest to read and material No. 4 the second easiest. The first two (participants A and B) complained that the wavy line design was the most difficult to read and No. 5 with vertical letter arrangement was next challenging, due to unfamiliarity with the vertical direction of words and letters. Participant C found material No. 5 most challenging to read, for the same reason.

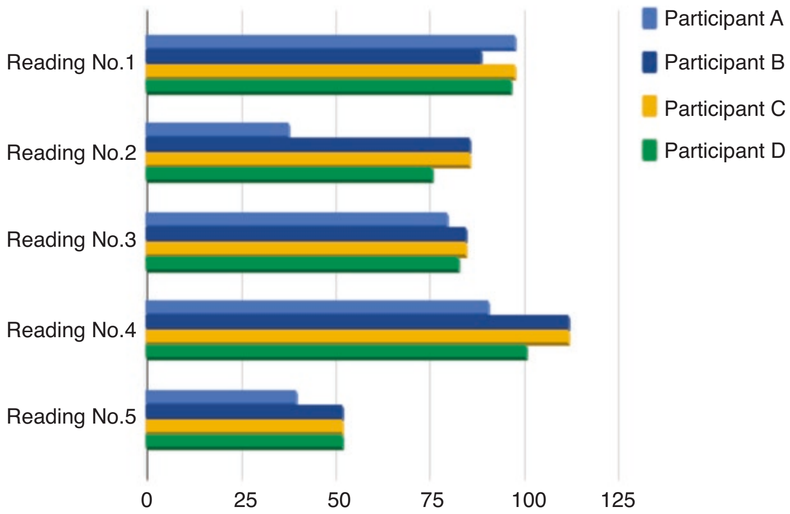

Fig. 1 Comparison of participant's reading speed in different experimental designs. Participants A, B, C, and D were provided with five types of reading materials in different experimental designs. Reading material No. 1 displayed in Appendix 1 was normal print with Times New Roman font size 12. Reading material No. 2 was wavy lines with 95 words in total and reading material No. 3 was a design purposely leaving one space between each letter; reading material No. 4 has the largest font and space between lines and with sans serif font style. Reading material No. 5 was designed with vertical direction of words and letters. (WPM: words per minute)

However, the results indicated that reading material No. 4, with the largest font and the biggest spacing between lines, enabled them to read faster compared to other designs (Fig. 1).

Limitations

The research study would generate more accurate results in a larger sample size. Due to time constraints, we were obliged to focus on a smaller sample size to produce results. The quantitative study was therefore unable to identify significant results within the data set. The research project requires more time and a larger sample size to accurately determine which design is more effective than the others. The research project will need to continue to connect and recruit more participants in order to make a scientifically sound conclusion with additional qualitative and quantitative data collection (Fig. 2).

Ethical Considerations

The participants were made fully aware of the objective and sequence of the research study, and their participation in this research study is completely voluntary. The research study has minimal risks, as it does not involve sensitive topics and the

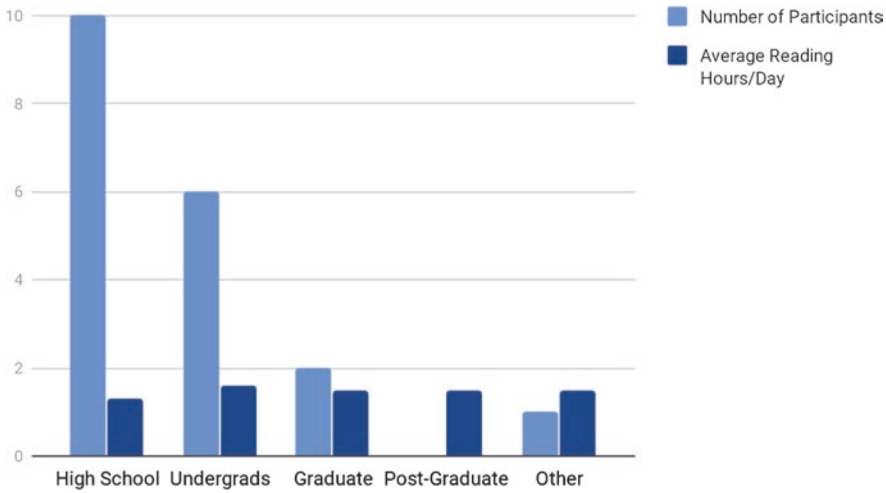

Fig. 2 Survey result – educational level
* This result from Qualtrics survey indicated that most of dyslexic readers graduated from high school; additionally, 22% are undergrad and 11% postgraduate degree holders

process does not in any way harm participants. The personal information of participants will not be shown in any circumstances. All collected data will be destroyed once the research study has been completed (Fig. 3).

Suggestions for Further Research

Further investigation of the experimental procedure is needed in order to help the interview process develop smoothly. At the beginning of the interview, researchers should inform participants whether they should read aloud or read quietly or allow the participants to choose their preferred method. A stopwatch should also be tested in order to record the experimental result accurately and precisely. Building trust and connection with participants is an important first step during the process of recruiting participants (Fig. 4).

Further research on the reading speed of individuals with dyslexia should include a larger sample size, and a deeper analysis should also be conducted. This could cover further investigation into what hinders their reading speeds through interviews, surveys, and observation of their struggle with certain words and each material format. In addition, new reading materials could be provided similar to Nos. 3 and 4 to further streamline which material presents the greatest ease for the dyslexic readers.

Implications/Conclusion

Interviews, surveys, and close observations were very helpful in collecting the primary data to enable us to reach our results.

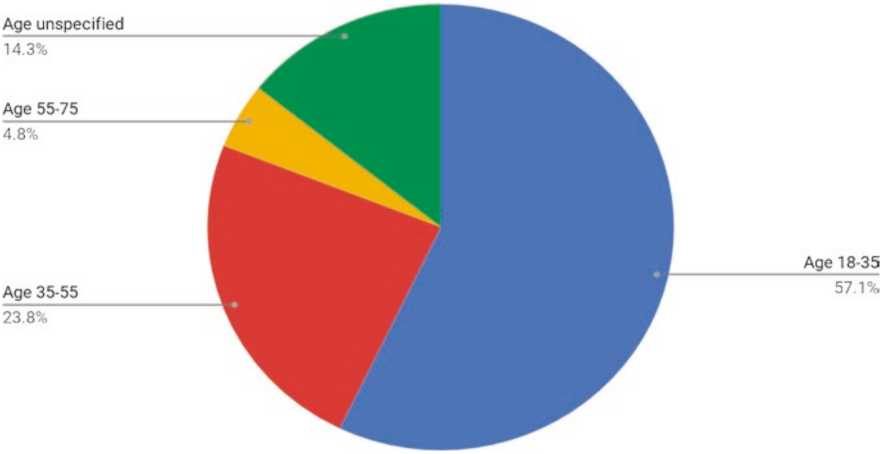

Fig. 3 Survey results – age group
* This pie chart indicates that the survey was conducted among adult dyslexic readers between the ages of 18 and 75 – among which 57% of the participants are young adults from the ages of 18 to 35

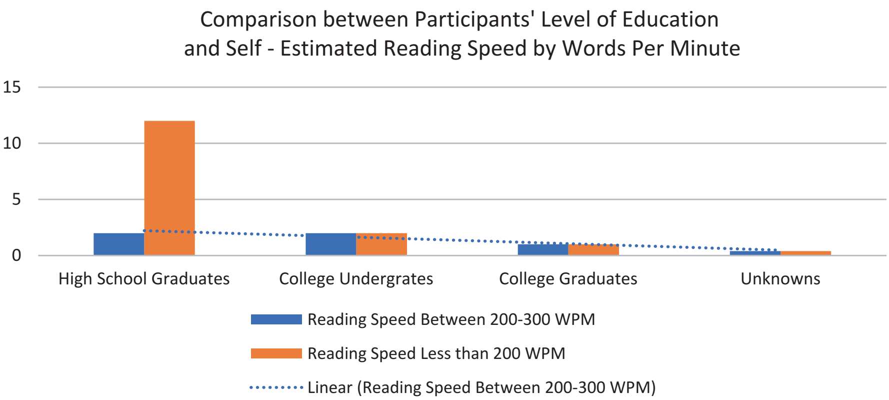

Fig. 4 Self-Estimation of Reading Speed in Words Per Minute
* The following bar graph indicates the estimated reading speed, with words per minute given by participants in the survey. However, this self-estimated reading speed has not been tested by researchers

The currently limited result of the research seems to indicate that dyslexic readers are prone to be negatively impacted by the narrow proximity of letters and lines. When the spacing of words and sentence lines is increased, participants showed improvement in reading speed and expressed that they were more comfortable. In conclusion, the research project would require more time and a larger sample size to indicate which design is most effective. The research project will need to continue to connect and recruit more participants in order to make a scientifically sound conclusion with additional qualitative and quantitative data collection.

Appendix 1: Interview Notes and Words per Minute Record

Participants	Readings Reading No. 1 172 words	Reading No. 2 95 words	Reading No. 3 82 words	Reading No. 4 135 words	Reading No. 5 48 words	Interview notes
Participant A	1 minute 45 seconds [a] Result might be invalid with the watch clock set as timer Participant read quietly	2 minutes 31 seconds [a] Feeling difficult to read, the worst piece of reading material Participant read quietly	1 minute 1.7 seconds [a] The **easiest** material to read, participant liked the font and line space arrangement Participant read quietly	1 minute 28 seconds [a]**Second easiest** material to read Participant read quietly	1 minute 12 seconds [a] Second hardest to read due to unfamiliar spatial arrangement Participant read quietly	Interview location: ICB building Interview media: Skype (UK) Date of interview: Nov 10, 2018 Interviewer: Rachel Brotherton, Linlin Li
Participant B	1 minutes 44.95 seconds [a] Result might be invalid due to participant read it out loud and not understanding its meanings	1 minutes 6.90 seconds [a] Read quietly, and need help to understand the meaning due to unfamiliar with its spatial arrangement	1 minutes 6.90 seconds [a] Read quietly Comment: **Easiest** material to read, participant liked the font, space arrangement, and its contents with good understanding	1 minute 12:12 seconds [a] Read quietly Comment: **Second easiest** material to read	0 minute 55.40 second [a] Feeling **easier to read** even though the letter direction and its vertical arrangement is unfamiliar	Interview location: ICB building Interview media: Face time (USA) Date of interview: Nov 10, 2018 Interviewer: Rachel Brotherton, Linlin Li Participant read quietly
Participant C	1 minute 47 seconds [a] Read softly, loud enough to be heard	1 minute 16 seconds [a] Read softly, loud enough to be heard	1 minute 0 second [a] Read softly, loud enough to be heard	0 minute 58 seconds [a] Read softly, loud enough to be heard	1 minute 16 seconds [a] Read softly, loud enough to be heard	Interview format: Virtual Interview media: Face time Date of interview: Nov 19, 2018

Participants	Readings					
	Reading No. 1 172 words	Reading No. 2 95 words	Reading No. 3 82 words	Reading No. 4 135 words	Reading No. 5 48 words	Interview notes
			Comment: **Easiest** material to read	Comment: **Second easiest** material to read	Comment: **Most challenging** to read because of unfamiliarity with letter arrangement	Interviewer: Latifatu Seini
Participant D	1 minute 45 seconds [a] Read quietly	1 minute 14 seconds [a] Read quietly, used finger tracking Comment: The **third difficult** context to read	1 minute 14 seconds [a] Read quietly Comment: The **second favorite** material to read but also the second more difficult one	1 minute 20 seconds [a] Read quietly Comment: The **easiest** and favorite context to read	0 minute 55 seconds [a] Read quietly and used finger tracking Comment: The **most challenging** to read because of unfamiliarity with letter arrangement	Interview format: Face-to-face Interview location: Bruton Memorial Library Date of interview: Nov 24, 2018 Interviewer: Rachel Brotherton

[a]The table below recorded the interview data collected from in-person interviews or utilized interactive technologies to conduct interview conversation with the participants. Both methods required the participants completing the same five instructional design (aka new reading material) assignments created by the researcher

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Interdisciplinary Research Collaboration: An Option for Advancing Your "Unpublishable" Research

Pamela C. Moore

Introduction

Your dreams are crushed: Your well-planned and executed research project has ended in insignificant results. Not only are your chances for publication slim to nonexistent, but the benefits you envisioned for extending your findings to other fields of study have also dissipated. This is not an uncommon scenario among researchers and one that I experienced in my first foray into the wonderful world of educational research. I consider my experience as a fortunate misadventure because it has forced me to look deeply into the research culture. I have concluded that instead of discounting some research studies as unpublishable due to insignificant or negative findings, these studies have the potential to advance knowledge for the good of society as well as to advance the personal goals of the researcher.

I present my argument by sharing my journey from a "failed" research project to the discovery of what I term four rules of conduct, typifying pervasive customs in the academic and publishing cultures. The result of following these rules of conduct may explain the dearth of published research with statistically insignificant results or negative findings. The rules of conduct can be described as (a) the "publish or perish" rule, (b) the "hoard until it's published" rule, (c) the "what happens in Vegas stays in Vegas" rule, and (d) the "reward the positive" rule. I highlight the underlying reasons for following these rules and the potential detriment to the research community. I propose that interdisciplinarity collaboration is a viable way to not only advance a researcher's personal goals but also to fulfill the ultimate goal of research, beneficence toward society. I conclude with suggestions for creating beneficial collaborations across disciplines.

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My Insignificant Story

My dissertation research was a quantitative study that investigated the effect of an online instructional strategy on illness script development for first-year physician assistant students. The findings were both statistically insignificant and unexpected. The statistically insignificant results were due to the small sample size: The unexpected results were due, I believe, to the lack of robust participation by the members in the experimental group. The data collection period for the study was 30 days. Unbeknownst to the experimental group participants, their involvement in the research study was monitored. Of the 30-day treatment window, the experimental group engaged with the instructional strategy for only 1.96 days (Moore, 2018). Although I was disappointed in the end results, I was undauntedly confident that I could publish my research as a pilot study, worthy of larger repeat studies and ultimately resulting in generalizability to other fields that involve diagnostic abilities. Reality began to set in, however, with my first manuscript feedback from reviewers indicating that my results were not worthy of publication. Still undaunted, I decided to explore the surely widespread problem of poor participation in online research studies. However, through my unsuccessful search of the literature for online studies with poor participation, I experienced the truth of what one researcher has noted, i.e., "lack of participation is a likelihood for any participant-based research, but one that is not often discussed in scholarship" (Dich et al., 2017, p. 3). Trying in vain to find studies with poor participation led me to expand my search to any publications of other research "failures," such as insignificant findings. Yet again, my search proved futile. I then began to ponder the possible reasons underlying this "loud" silence of unpublished insignificant or negative research findings.

Systemic Reasons for the Loud Silence

Why is there so little published about surely a widespread, common experience among researchers? How can we learn from each other's "mistakes" if we cannot read about them in the academic literature? I believe the answer is rooted in what I view as four foundational rules of conduct in contemporary research and publishing cultures.

Publish or Perish

The first rule is the "publish or perish" rule. Publish or perish is a phrase in academia that refers to the pressure to publish for academic success including contract renewal, tenure, or promotion (Lee, 2014). Davies and Felappi (2017) affirmed this publish or perish reality by noting that academic institutions often measure the worth of job applicants and faculty employees by their publication records. This tendency to use publication records as a measure of employee worth may be explained by the findings of a research study revealing that North American universities have adopted a "corporate culture with increased accountability and outcomes" (Holosko & Barner, 2016, p. 278). Extended measures of researcher productivity and quality, beyond the number of publications an employee has produced, are having publications in high-ranking journals and the number of times a publication has been cited (Barner, Holosko, & Thyer, 2014). Compounding this problem of using publication records as a measure of success is the competition for research grants where funding decisions are based on a researcher's quality, again, as measured by published research (Kun, 2018). In short, the "publish or perish" rule can make sharing insignificant results a behavior that is not self-promoting for the researcher. With such measures of personal worth, a researcher is not rewarded by sharing research studies with insignificant findings. In fact, such sharing may prove detrimental to a researcher's academic success.

Hoard Until It's Published

The second rule of conduct that underlies the reason for non-sharing of insignificant or negative research findings is the "hoard until it's published" rule. This is a natural consequence of the "publish or perish" rule. A research study designed to explore the effect of agreed-upon collaborative rules in a research project discovered that participants viewed data sharing as a "generous act." This attitude reflected the traditional view that data belongs to the principal researcher and is normally not shared with others due to a research culture based on "competitiveness and possessiveness" (Kits, Angus, MacLeod, & Tummons, 2019, pp. 29–30). If the normative view among researchers is that sharing research data before publication reduces one's competitive edge, then it follows that hoarding research data, research findings, and research ideas are requirements to survive in a "publish or perish" environment. This, of course, explains why significant research findings may be hoarded until safely published, but can it also account for the non-sharing of insignificant or negative research findings? It is a reasonable explanation if the researcher hopes to continue his/her research efforts until more favorably publishable results occur. In either case, as noted by Kun (2018), it is unreasonable to expect an individual to act contrary to his or her best interest as it pertains to advancement in academia (p. 10).

What Happens in Vegas Stays in Vegas

The third rule of conduct that drives the culture of non-sharing is the "what happens in Vegas stays in Vegas" rule. This rule is an extension of the first two rules. The "publish or perish" rule would demand that insignificant results would remain "in

Vegas" due to the non-promoting aspect of such sharing. The "hoard until it's published rule" would require the secreting of research results until deemed safe to share, fearing that one's ideas may be pilfered due to what Park (2018) describes as one of the dangerous side effects of the "excessive research outcome-oriented competition in academia" (p. 2).

Reward the Positive

Finally, perhaps the most potent rule of conduct that can suppress research findings from being shared is the "reward the positive" rule. This rule is better known in the publishing world as the positive outcome bias. This publication bias was identified in one study as one of 35 biases that could occur in research and refers to the tendency of publishers to select for publication studies that have positive results (Sackett, 1979). As a case in point, Emerson et al. (2010) submitted two research studies to two medical journals for peer review by 210 reviewers. The studies were identical except for the statistical outcomes. One study had a positive outcome: The other study reported no differences between the control group and the experimental group. Five errors were purposefully added to the manuscripts. The findings showed that reviewers were more likely to recommend for publication the manuscript with the positive outcome by 97.3% compared to an 80% recommendation for the no-difference study. Reviewers were twice more likely to detect the errors in the no-difference manuscript than the identical errors in the positive outcome manuscript. Finally, reviewers gave higher points for the methods section of the positive outcome manuscript than the identical methods section of the no-difference manuscript (Emerson et al., 2010).

In summary, the phenomenon of non-sharing of insignificant or negative research findings may stem from organizational and individual behaviors and values. Organizations that promote research efforts by their employees are apt to assess the employees by using the bibliometrics of publications, works cited, and the importance of the publishing journal. Grant awarding institutions are more likely to award funding to researchers who have a positive history of publications. Positive outcome bias may be present during the peer review process of a publishing organization resulting in a higher acceptance rate of studies with significant findings. Such a research culture coupled with bias in the publishing culture breeds a spirit of survival that results in researchers discounting, rejecting, and ultimately not sharing their insignificant or negative research findings.

Consequences of Not Sharing

Hiding or hoarding insignificant or problematic research findings seems to be a reasonable, even safe, method of reaching personal employment and research goals. However, is there a downside of non-sharing that exacts a higher personal or societal cost? A personal cost of non-sharing could be a missed opportunity to improve one's knowledge or skills. Dich et al. (2017) explored the results of sharing research "failures" within a faculty learning community. The researchers concluded that failures can be a central part of the advancement of personal scholarship. For example, sharing a study with colleagues that had no participation resulted in the researcher delving into possible motivations for learners to participate in online activities. Sharing a research study that had insignificant findings inspired the researcher to revisit the assumptions about the population. A shared research study that had stalled over technical problems was improved with a colleague's help and became publishable (Dich et al., 2017).

A second personal and, perhaps, an institutional cost to non-sharing is that time and money may be wasted. McCuen (2018) has noted that unethical behavior by a researcher, such as dishonesty in the findings of a published study, could misdirect future research, thus wasting time, funds, and a "loss of excellence" in the work of the future researcher (p. 3). It is also conceivable that the same results would ensue, not from unethical behavior of the researcher, but from the withholding of potentially valuable negative research findings. At the very least, sharing research problems may help other researchers avoid experiencing the same problems and, therefore, avoid wasting their time and funding. Eysenbach (2018) goes even further in suggesting that not publishing negative research results could incorrectly skew literature reviews toward positive outcomes.

Breaking the Silence Through Interdisciplinary Research Collaboration

One must weigh the benefits of sharing negative research results against personal costs. If the benefits truly outweigh the risks, then the question becomes: How best to mitigate the associated risks of sharing? I believe the answer lies in interdisciplinary research (IDR) collaboration, which may be a better venue for sharing our unpublished research ideas and studies and be a truer expression of our personal identity and backgrounds.

Advantages of IDR Collaboration

There are many advantages to IDR collaboration. In the previously discussed study by Dich et al. (2017), the key factor in the success of sharing research problems was having a network of colleagues that represented different disciplinary fields and perspectives. As Morss, Lazrus, and Demuth (2018) suggest, "such [IDR collaborative] work can frame new research questions, develop novel approaches, and generate innovative insights across and within disciplines. It can also address complex questions at the intersections of established fields, beyond what the collection of contributing fields can produce on their own" (p. 1).

There are additional reasons to seek IDR perspectives and collaborations that are personally beneficial to a researcher. IDR collaborations can provide the opportunity for personal growth. Experts in other disciplines can enrich one's understanding of a research problem by providing a new lens in which to view different aspects of one's research. Experts in other fields can fill the gap in one's knowledge by providing technical knowledge unique to their disciplines. Conversations with experts in other fields may even force a researcher to re-evaluate his/her personal limitations, thus opening the door for new learning (Dich et al., 2017; Hibbert, Siedlok, & Beech, 2016).

IDR collaborations can also increase a researcher's autonomy in reaching his/her goals. One study revealed that academic institutions tend to control and effectually limit the research scope and activities of their employees. Furthermore, academic institutions are not as prone to embrace IDR collaboration as are research institutions. Therefore, it behooves the researcher in academia to exercise autonomy in reaching one's personal research goals. Proactively pursuing collaborative opportunities with experts in other fields is one way to expand the range of choices for personal improvement and advancement (Hibbert et al., 2016; Ribeiro, 2016).

IDR collaboration offers the possibility of increased and longer sustained citing of one's research articles. In a bibliometric research study of cognitive science and educational research, findings reveal a higher citing rate for multi-disciplined research studies than single-disciplined research studies. For educational articles, the window for citations, which decreases over time due to becoming outdated information, is a longer window for IDR topics than for single field research. Finally, IDR research articles from closely related fields may have a wider range of influence than mono-field related research (Kwon, Solomon, Youtie, & Porter, 2017).

Personal Commonalities with Interdisciplinarity

In addition to the affordances of IDR collaboration, some of us may have a personal commonality with the concept of interdisciplinarity. If we were to reflect on our own backgrounds, many of us may discover that we are products of interdisciplinarity. In my own case, my educational background includes four disparate fields: mathematics, computer science, biblical counseling, and instructional design for online learning. My experience is not uncommon in the field of education: A 2017 survey of US university doctoral graduates in the field of education shows that 76% earned a bachelor's degree in a different field than their doctorate and 46.3% earned a master's degree in a differing field than their doctorate (NCSES, 2018).

Even if one's background does not reflect interdisciplinarity, there are professions that are inherently interdisciplinary. One such professional field is my own field of instructional design. Instructional designers are employed in a variety of settings, including education, business, government, military, health, and nonprofit organizations (Larson & Lockee, 2004). Additionally, instructional designers must be competent across multiple domains such as instructional design, technology, management, communication, and interpersonal skills (Klein & Kelly, 2018). Since instructional design traverses multiple settings and multiple skill sets, it logically follows that instructional designers, including instructional design researchers, should be natural role models of interdisciplinarity.

Suggestions for Beneficial Collaboration Across Disciplines

Given the advantages of IDR collaboration, coupled with the fact that many of us already incorporate the spirit of interdisciplinarity, how can we proactively and positively pursue interdisciplinarity sharing in our research efforts? I suggest four steps for pursuing and creating a beneficial blend of research collaborators.

Choose Your Comfort Level

First, we must be aware that collaboration can be of differing levels of involvement and choose the level in which we are the most comfortable. According to Hibbert et al. (2016), the most basic collaborative relationship is the simple transactional exchange of ideas. The sharing of ideas may even be a one-way sharing. Another level involves temporally shared tasks, such as a research project. The most intensive collaborations are enduring relationships resulting in emergent learning and new opportunities.

Avoid the Limitations

To achieve any level of IDR collaboration, we should watch out for danger zones that may be limiting our attitude or ability to expand our relational horizons beyond our own discipline. The first delimiting area may be one's existing network. Researchers Siedlok, Hibbert, and Sillince (2015) discovered that a researcher's personal network has a strong influence over interdisciplinarity. A personal network with high levels of discipline similarity decreases interdisciplinarity (Siedlok et al., 2015). The second restrictive area may simply be membership in an academic department which has been shown to decrease interdisciplinarity in research efforts (Ribeiro, 2016). The third delimiting factor to IDR collaboration could be one's personal beliefs and values. According to Siedlok et al. (2015), the desire to avoid risks, to remain in one's comfort zone, and to hold fast to a methodological approach or theory detracts from interdisciplinary explorations. On the other hand, an interdisciplinarity perspective requires humility, an acceptance of one's own limitations, curiosity, and an openness to change and to new ideas.

Choose Your Mix of Disciplines

Since personal networks are central to effective IDR collaboration, the next step is to ensure that one's network includes the right mix of disciplines. A researcher should seek proximal disciplines that are related to his/her field. Research indicates that interdisciplinary research studies that are too distal are less likely to be highly cited. Distal relationships are collaborative fields that are extremely different, with little shared knowledge. On the other hand, proximal disciplines, representing a middle ground of fields that share related knowledge, have a greater citing rate (Yegros-Yegros, Rafols, & D'Este, 2015). Other studies have shown that highly cited IDR articles include those which exhibit knowledge mainly from a primary discipline and borrow knowledge from other disciplines, as opposed to equal knowledge from all disciplines (Wang, Thijs, & Glänzel, 2015). More specifically, in social science research, multi-disciplined studies that have the most cite impact are those that have less than 60% of sources from disciplines other than the primary discipline (Larivière & Gingras, 2010).

After evaluating our personal networks, how can we be intentional about adding members who may advance our desire for IDR collaboration? One obvious way is to seek collaborative members within our university affiliations, professional conferences, and within Internet research platforms. Another method to find IDR collaborators, as suggested by Siedlok et al. (2015), can be found by attending events from different communities of learning to expand our exposure to diversity. In these events, we should be careful, however, to "up frame" our research topic as we talk with other researchers. This simply means "generalizing and de-contextualizing the research problem" to appeal to the interests of researchers from other disciplines (Siedlok et al., 2015, pp. 100–101).

Protect Your Work

The final step to forming a beneficial collaboration is to address the protection of one's work in IDR collaborations. There are several things one can do to mitigate the risks of one's ideas or unpublished research from being plagiarized, stolen, or not receiving the proper credit. At the most basic level, Gladwin (2018) suggests that we surround ourselves with researchers of other disciplines who will respect the code of ethics regarding plagiarism. We should make written agreements and follow-up on all conversations with an emailed summary (Gladwin, 2018). Furthermore, we could utilize preprint service platforms to protect our ideas, similar to a registry of prospective trials in medical research (Campbell, Loving, & Lebel, 2014; Harriman & Patel, 2016). An example of a preprint service platform for social science research is the Social Science Research Network (SSRN, n.d.). Another strategy is to publish one's work as a white paper or working paper in one's affiliated institution or through an Internet research community.

Conclusion

In summary, it is commonly understood that academic research is for the purpose of expanding the knowledge base and "should have as its ultimate goal the betterment of society" (Salkind, 2012, p. 4). I have argued that unpublished research studies that have resulted in insignificant or negative findings can be considered worthy of sharing. Such studies can add value to future research efforts, be a catalyst for personal growth, and perhaps help to avoid skewed positive results in the literature. However, obstacles to the sharing of insignificant or negative findings that stem from research and publishing cultures must be overcome. One way to surmount these obstacles is for the individual researcher to explore the possibility of IDR collaboration. Such collaboration offers both benefits and risks. The benefits may include new skills and knowledge added to the researcher's toolbelt, new research opportunities, publication opportunities, and increased autonomy in reaching personal goals. One of the obvious risks is plagiarism or stolen research ideas. I have offered ideas to reduce these risks and suggestions for pursuing beneficial IDR collaboration. I especially challenge those of us who are products of an interdisciplinary background or hold professional positions that require a transcendence of disciplines to be the forerunners and role models of IDR collaboration.

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The Centrality of Interdisciplinarity for Overcoming Design and Development Constraints of a Multi-user Virtual Reality Intervention for Adults with Autism: A Design Case

Noah Glaser, Matthew Schmidt, Carla Schmidt, Heath Palmer, and Dennis Beck

Multiuser virtual environments (MUVE) are graphically detailed, three-dimensional (3D) digital environments holding a variety of affordances that make them ideal tools for providing controlled scenarios that can promote learning and assessment (Dalgarno & Lee, 2010). The learning affordances of 3D virtual environments also appear to be well aligned with the learning needs of nontraditional learners, like those with disabilities such as autism (Conway, Vogtle, & Pausch, 1994; Strickland, 1997; Dalgarno & Lee, 2010; Parsons, 2016; Glaser & Schmidt, 2018). However, creating MUVE is a remarkably difficult task for educational technologists (Bartle, 2004; Bricken, 1994; Hirumi, Appelman, Rieber, & Van Eck, 2010), requiring an interdisciplinary team of educators, researchers, content experts, programmers, 3D modelers, designers, developers, and more. This challenge is further amplified when designing MUVE for individuals with autism, who exhibit substantial variability in the unique challenges they face (Parsons, 2016).

Autism is a spectrum disorder (Wing, 1993) characterized by a series of impairments centered around social, communicative, and cognitive abilities (Wing & Gould, 1979). Deficits resulting from an ASD diagnosis can severely impact an individual's quality of life and ability to function independently. Left untreated, problems can become exacerbated and lead to social isolation, difficulty maintaining relationships, and hardships with finding meaningful employment (Eaves & Ho, 2008; Frith & Mira, 1992). Despite decades of research, social, communicative, vocational, and accommodation-related outcomes for adults with ASD remain poor

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(Billstedt, Gillberg, & Gillberg, 2005; Eaves & Ho, 2008; Howlin, Goode, Hutton, & Rutter, 2004; Parsons, 2016). To assist in reducing uncertainty of outcomes, the National Professional Development Center on Autism Spectrum Disorder (NPDC) has detailed evidence-based practices that can be implemented in behavioral interventions for individuals with autism (Bogin, 2008) and, importantly, has advocated for technology-aided instruction.

One technology that has been considered as potentially efficacious with this population is virtual reality (VR). Interest in VR technologies for individuals with ASD has been growing for decades (Aresti-Bartolome & Garcia-Zapirain, 2014), as researchers are increasingly turning to VR as a means to provide both therapeutic and educational platforms for this population. This trend is due in part to evidence that suggests VR is intrinsically reinforcing for people with ASD, due to the technology's visually stimulating and appealing nature (Schmidt et al., 2019). VR platforms also have a variety of technological affordances which align with the instructional needs of this population (Glaser & Schmidt, 2018). These benefits include the predictability of the task, ability to control system variables and complexities, realism of digital assets, immersion, automation of feedback, assessment, reinforcement, and more (Bozgeyikli, Bozgeyikli, Katkoori, Raij, & Alqasemi, 2018; Bozgeyikli, Raij, Katkoori, & Alqasemi, 2018). Research suggests that MUVE have potential to promote acquisition of social, communicative, and adaptive competencies for individuals with ASD (Glaser & Schmidt, 2018; Parsons, 2016; Schmidt et al., 2019), thus providing a preliminary basis of support for VR as an intervention modality for individuals with ASD (Mesa-Gresa, Gil-Gómez, Lozano-Quilis, & Gil-Gómez, 2018). Our project, entitled Virtuoso, is a VR-based MUVE, delivered using fully immersive VR headsets (i.e., HTC Vive, Oculus Rift), and developed to promote adaptive behavior skills for adults with ASD.

Project Description

Virtuoso was developed for participants with ASD in an adult day program called *Impact Innovation.* A goal of *Impact Innovation* is to provide participants with vocational opportunities that are oftentimes geographically distant from the university campus where the program is housed. With transportation being one of the most cited barriers to access community settings for individuals with disabilities (Allen & Moore, 1997; Carmien et al., 2005), the focus of Virtuoso is promoting adaptive behavior skills related to using a university shuttle public transportation system. To this end, we designed a VR curriculum based on a detailed procedural task analysis (Jonassen, Tessmer, & Hannum, 1998). Research suggests that participants' sense of immersion and embodiment in a collaborative virtual space can lead to the tasks in which they engage taking on a deeper meaning (Mennecke, Triplett, Hassall, & Conde, 2010). In addition, VR technologies may help to convey meanings and symbolic measures of real-world activities (Wang, Laffey, Xing, Ma, & Stichter, 2016; Wallace, Parsons, & Bailey, 2017) that can be enhanced through behavioral and visual realism of in-world assets (Parsons, 2016). A key premise that supports these claims is the "assumption of veridicality," i.e., if VR experiences are sufficiently authentic and realistic, people will interact with and respond similarity in the digital world as they do in the real world, which arguably can promote transfer from the prior to the latter (Parsons, 2016; Yee, Bailenson, Urbanek, Chang, & Merget, 2007). However, embodiment of a high level of realism in our VR-MUVE required a formidable assortment of expert knowledge and skills, including graphic design, 3D modeling, visual scripting, object-oriented programming, in-depth knowledge of computer and VR hardware, application of learning theory, photography, computational thinking, and even drone piloting.

A key problem that our team grappled with was creating environments that were realistic to the point that they were very easily recognizable. This included geometric accuracy, photographic fidelity, lack of distortion, appropriate scale, etc. While problems of this nature are well understood in commercial contexts, commercial solutions are not always directly applicable in research contexts. That is, limited budgets, capacity, and expertise significantly constrain research teams' abilities to confront the design and development challenges presented by VR head-on. Importantly, complexities are amplified when working within a small development team due to limited resources. Solutions must be devised that are sensitive to these constraints. Although it is generally accepted that developing VR interventions in the field of autism research is fraught with challenges, very little has been written to chronicle those challenges and how they can be approached by researchers. Further elaboration is needed to detail how researchers in the field of VR for individuals with ASD encounter and overcome design and development challenges. To this end, we provide here a narrative of our design and development process so as to signpost salient challenges and how interdisciplinary methods and processes were instrumental in overcoming those challenges. Although our core team brought expertise in many disciplines (e.g., special education, applied behavior analysis, engineering, geography, instructional design, educational game design, mobile learning, information technology, computer science, etc.), further internal skills development as well as external expertise were required to successfully create our proof of concept. The following sections detail our experiences in the form of an instrumental case study.

Methodology

Lessons presented here are intended to inform others in the field as they devise solutions to their own design and development challenges. Hence, the purpose of this instrumental case study is to provide insight into the complexities of Virtuoso's design and development, with a particular focus on the interdisciplinary nature of our research. Instrumental case studies seek to provide insight into an issue, to redraw generalizations, or to build theory (Stake, 1995). Our focus relates to the assumption of veridicality and the premise that the realism provided by VR potentially can promote transfer of skills from a VR environment to the real world. At issue is the substantial research-to-practice gap concerning how designers can embody these principles in practice. We specifically examine the intricacies of leveraging limited resources so as to imbue sufficient realism and authenticity into a virtual public transportation simulation with the aim of promoting transfer of skills for individuals with autism. Virtuoso required development of an interdisciplinary set of skills as well as external expertise. For the purposes of this chapter, we define interdisciplinarity as designing and implementing methods, processes, and skills from many fields during each step of the project (Klaassen, 2018). Incorporating the knowledge, skills, and traditions of different disciplines allows for consideration of divergent ontologies and epistemologies, thereby engendering ongoing negotiation and integration as project needs shift and project members recognize these disparate methodologies' relevance to one another and their potential synergies (Modo & Kinchin, 2011).

Key Participants

This case study is bounded by the experiences of three core members of the Virtuoso team who engaged specifically in software development ($n = 3$; all male), including (1) one instructional design and technology professor, (2) one instructional design and technology PhD candidate, and (3) one engineering undergraduate student. Members primarily contributed expertise in instructional design, information technology, software development, development of virtual worlds and assets, and educational game design.

Data Collection and Analysis

Data are presented from the perspective of the first author, a PhD candidate in instructional design and technology, relative to his involvement in development of the intervention. Experiences were compiled using autoethnographic methods following completion of a functional intervention prototype (Bruner, 1993; Freeman, 2004). Project artifacts were consulted to assist with recall (Goodall, 2001), including screenshots, 3D assets, videos, procedural analysis documents, meeting minutes and communications, rapid prototypes, and project documentation. Artifacts were organized based on principles of task authenticity and environmental realism and how the principle was achieved relative to each asset or virtual element that was reviewed. This process led to four development processes being identified as representative of the principles, specifically, the development of realistic (1) terrain, (2) campus buildings, (3) interiors, and (4) task scenarios. Following this, autoethnographic methods were used to make sense of epiphanies (moments of experience that serve as a turning point in one's understanding) perceived to have greatly impacted the phenomena of focus in this study (Denzin, 1989). When epiphanies were identified, the lead author would engage in a reflective writing process, detailing recalled challenges of embodying design principles and chronicling how disparate and nonintuitive approaches were required to create the initial prototype. These reflections were then consulted for sense- and meaning-making relative to these transformative moments in our design process, ultimately leading to a holistic representation of MUVE design for individuals with ASD, which we characterize here as transitive, ill-defined, and complex.

The Case Narrative

The assumption of veridicality suggests a need for physical realism (e.g., terrain, buildings, and building interiors) as well as task fidelity between the real world and the virtual world. Bringing together all of these pieces to create a learning environment that could provide sufficient realism to fully instantiate a diverse array of design guidelines presented significant challenges. Table 1 below outlines the interdisciplinary processes involved in realizing the principles across the four development processes outlined in the previous section.

Realistic terrain is imperative because the terrain acts as an underlying unifying element upon which the virtual world is based. This extends not only to the space in which objects and avatars act and interact but also the activity space. The assumption of veridicality suggests a need for terrain that simulates the real experience of performing activity on campus. While a simplistic, flat terrain would have been simpler, it is likely that it would have substantially diminished sensations of realism and potentially distorted participants' sense of presence or "being there." Buildings would have been off-scale and incorrectly positioned. For example, the campus is hilly and many buildings have multiple entrances on different floors. Entering from one side might bring one to the first floor while entering from another side might bring you to the fourth. However, creating terrain that accurately represented the contours of the earth was a challenge that was outside our collective expertise. How does one model real-world terrain in a virtual world? What about other topographical elements, such as building placement and roads? How are all of these elements combined? And, ultimately, how could these combined elements be imported into a virtual reality simulation? These are problems that have long been addressed in the field of video game development; however, the resources available to game development studios differ significantly from those available to academic institutions. Given the constraints of our design and development resources, our options were either to go with the simple approach and thereby threaten the validity of our design principles or to engage in an ill-defined process to determine how to solve the topography problem on our own.

Atop the terrain are the campus buildings themselves. We reasoned that buildings that were accurate representations of their real-world counterparts were imperative to promote the intended outcomes suggested by the assumption of veridicality.

Table 1 Interdisciplinary processes and skills required to create Virtuoso

Affordance	Challenge	Interdisciplinary requirements	Specific examples
Realistic terrain			
Promotes sense of presence by emulating lived experiences of actually walking on campus	Generating a geographically realistic contoured mesh with accurate representations of topography	Geography	Image editing
		3D design	3D editing
		Game design	GIScience
		Graphical design	Scripting
		Software development	
Realistic campus models			
Promotes sense of presence by emulating in situ environment for training. Helps promote assumption of veridicality	Modeling photorealistic campus models	Piloting	Photogrammetry
		Photography	Taking photographs
		Geography	Drone piloting
		3D design	3D editing
		3D editing	GIS extraction
		Modeling toolchains	Outline and extruding models
Realistic interiors			
Provides connection to real world by using a familiar space	Creating a highly realistic representation of an interior design	Architecture	CAD
		3D design	Converting blueprints into a 3D model
		Photography	Interior photography
Realistic tasks			
Provide realistic and accurate way of practicing skills to transfer from virtual platform to the real world	Creating a one-to-one representation of behaviors that both human avatars and in-world assets such as a bus would naturally undergo in the real world	Game design	System of least prompts
		Applied behavioral analysis	PHP programming
		Programming	JavaScript programming
		3D design	3D editing
		Videography	Game design techniques
		Instructional design	Shot ride-along footage
		Computational thinking	Created a task analysis
		Physics	Velocity calculations

However, buildings have complex architecture, and creating accurate 3D models of buildings is incredibly tedious and requires substantial expertise. We reasoned that architectural accuracy was less important than photographic realism and therefore concluded that campus models did not need to be entirely true to their real-world geometry. This is because participants would be engaging in activity around the buildings, but not specifically with the buildings themselves. Hence, we focused on creating photographically realistic architecture. However, for the interior designs of our MUVE, we took the opposite approach. This is because participants would be engaging in activity within the interior models, and close-up, therefore requiring far more precise approximations of real-world counterparts. Instead of focusing on photographic realism, we employed the actual architectural plans of the buildings. Based on the interior elevations and floor plans, we created highly realistic models of the *Impact Innovation* office space. This space provided users with a highly authentic-looking space to interact with an online guide and others. In the real world, *Impact Innovation* participants have their own cubicles and are exposed to a variety of activities in this office space. In the virtual world, this space provides users a connection to the real world and to their everyday lives. Importantly, the central component that connected elements of terrain, buildings, and interiors was the training activities to learn to use the university shuttle. We conducted a meticulous procedural task analysis in order to model how participants performed this task in the real world. The interdisciplinary task analysis process was made possible with the help of special education specialists and an applied behavioral analyst, who assisted in the development of a scripted set of routines and behaviors that precisely mirrored the activities that *Impact Innovation* participants would undertake in the real world. A variety of computer programming and game design skills were required to bring these pieces together.

Developing a Realistic Terrain

An early representation of how we set out to create our model is shown in Fig. 1. The terrain, including slopes and scaling, were obtained by extracting geographic information system (GIS) data from Google Earth. After extracting this GIS data, we were able to convert the data into a 3D mesh. In this early version of Virtuoso, we placed a screenshot of a map from Google Maps onto that geometric mesh to create a preliminary terrain of the university.

Next, we textured the terrain to include photorealistic representations of the roads, pathways, landscape, and topography. Initially, we opened the GIS mesh in Blender (http://blender.org; a free and open-source 3D modeling program) to manipulate the millions of polygons that made up the terrain. With the outline of the map placed over the terrain, we were able to garner rough approximations of the locations of pathways and grass. Photographs of the roads and topography were taken to allow for the realistic texture creation. While this process resulted in a more photorealistic representation of campus, the resulting product had a litany of issues.

Fig. 1 Screenshot of the campus terrain with a Google Map image placed onto a 3D mesh

Manipulating massive GIS meshes created problems with collisions, which resulted in "holes." This led to assets and avatars falling through the base of the world. Repeating textures were also too uniform and did not account for variations in coloring, texturing, and consistency across the terrain.

In the next iteration, we again returned to the GIS terrain that we extracted from Google Earth. Now knowing that editing the mesh could result in unforeseen errors, we ultimately decided to leave the geometry alone and to place the topography on top of the 3D object. In this prototype, we took a large high-resolution image of the university from Google Earth. We then placed it over the terrain like we had done with the Google Map image before, which resulted in a terrain that included the university's natural topography while maintaining an outline of the buildings to help with proper positioning.

Developing Realistic Buildings

While developing the terrain, we were concurrently developing 3D models of all campus buildings. This process took approximately 1.5 years of iterations to reach a level of fidelity that we deemed acceptable. By acceptable we mean that the models were (1) largely accurate in terms of geometric representation in relation to their real-world counterparts, (2) textured with photographic images that gave them the appearance of photographic realism, (3) not containing distortions to shape, shadow, and overall visuals that could result in sensory issues, and (4) were scaled appropriately.

To create the campus buildings, we first created approximations of the structures and then mapped images onto them to provide a degree of photorealism. To test this process, we created a fountain that existed on campus. Two studio members went onto campus and took photos of the fountain from varying angles and perspectives. These images acted as the textures of the model that was made. However, scaling this process was ineffective as lighting issues greatly impacted our ability to obtain high-quality photos while on campus. In addition, an inability to reach high angles prevented us from being able to fully capture stills from most of the buildings on campus. To address these issues, we began testing a process called photogrammetry.

Photogrammetry is the process of obtaining information about objects and the environment through recording, measuring, and analyzing photographic images and patterns (Mikhail, Bethel, & McGlone, 2001). We decided to test the procedure using a DJI Phantom Drone equipped with a video camera that could continuously shoot footage as it flew around a building from various heights, angles, and perspectives. Unfortunately, this idea proved to be untenable, as we uncovered safety and regulatory barriers that the university had in place which restricted when we could pilot a drone on campus. Such regulations prevented successful implementation. In addition, the technical challenges of video capture and conversion of photographs into a 3D mesh proved to be prohibitive. Despite this setback, we were still interested in using photogrammetry to create 3D models. Instead of capturing images by flying around the campus buildings, we decided to use the same process, but in Google Earth. Using different perspectives while capturing images of the buildings on campus provided a set of photos we were able to process using a photogrammetry software called Adobe ReCap (Fig. 2).

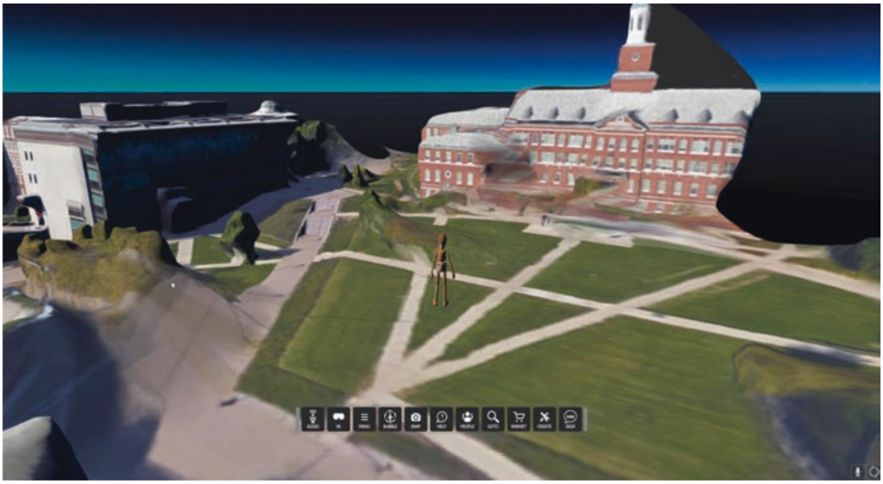

Fig. 2 A photogrammetrically created model, imported into High Fidelity

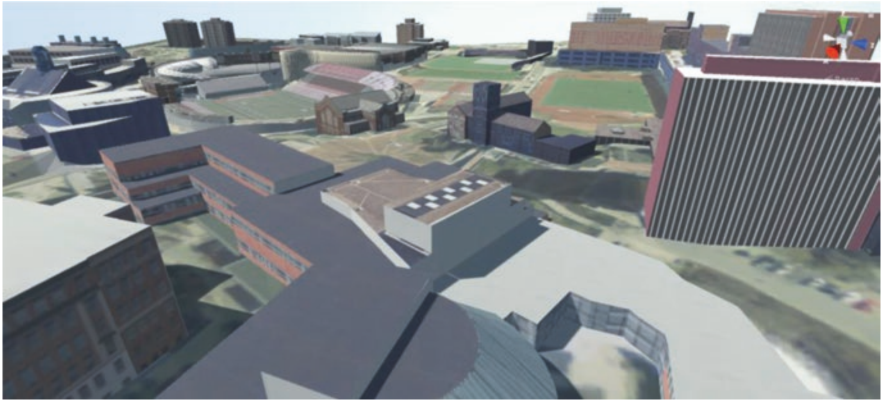

Fig. 3 Campus model created using a combination of GIS data, image editing, 3D modeling, and photogrammetry

The result of this process was a highly realistic, albeit flawed, model. There were multiple distortions that resulted from the process. As a result, we took the high-resolution image of the campus map and placed it onto a flat plane which allowed us to view the outlines of the campus buildings. We then opened the map in Adobe Illustrator, a vector image editor, and used the Pen tool to trace the outlines of the different campus buildings. After doing so, we exported the image as a Scalable Vector Graphics (SVG) and imported it into Blender. We were then able to extrude crude 3D shapes of the buildings. This process resulted in building models that were correctly scaled and positioned onto the terrain. The question then became how to provide and map textures onto the faces of the buildings. We returned to the photogrammetry process we had tested in Google Earth for creating a mesh. However, instead of using it to create the entire mesh with textures, it was used only for ripping textures that we could place onto the planes of the building faces (Fig. 3).

Developing Realistic Interiors

The next step of our intervention design required that we re-create a model from the *Impact Innovation* office suite. Given the results of extruding map outlines, we opted to do something similar using architectural blueprints. These were imported into architecture modeling software (Archilogic) and used to create a fully interactive 3D model. We then went to the actual office and took photos to create textures for the walls, floor, etc. Archilogic allowed us to import furniture, electronics, and other furnishings to better represent its real-world counterpart (Fig. 4).

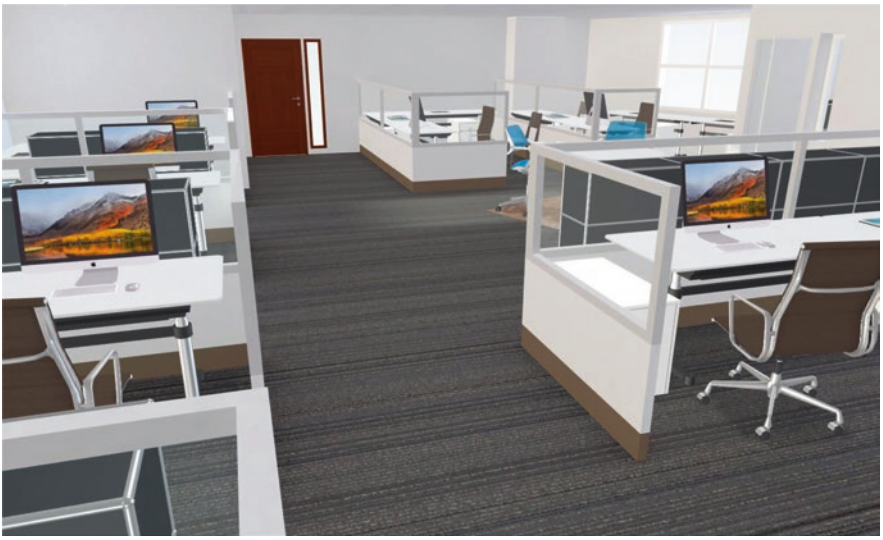

Fig. 4 Office model created using architectural modeling software

Developing Realistic Scenarios

Task analysis was performed at the outset of the Virtuoso project so as to determine the structure and nature of activities that would take place within the MUVE. This required assistance from an *Impact Innovation* staff member who was familiar with the day-to-day scheduling of the day program and was able to provide us with details of the behaviors associated with shuttle training. Moreover, we performed a ride-along, recording the staff member and a program associate completing these tasks to expand upon and improve the task analysis. We also worked with an applied behavior analyst to modify the tasks to include opportunities for interaction and behavioral prompts (Fig. 5).

Embodying realistic activity within the learning process required that we simulate real-world tasks in the virtual environment with a high degree of fidelity; therefore, we needed to develop a solution to bring the tasks to life into our 3D environment. This included creating a shuttle bus that was animated to arrive on a set schedule after participants had completed the prerequisite training steps. The virtual world toolkit we used for this, High Fidelity, was in early development with immature documentation and standards. The project's immaturity prevented us from being able to reliably create a solution to animate an object in our project. We had little choice but to script the provided physics engine to move objects from point A to point B. While this solution allowed us to animate an object, it did not allow for flexibility or elegance. Hence, we looked to the gaming industry for an animation solution. In the popular video game Fallout 3, there was a rideable train

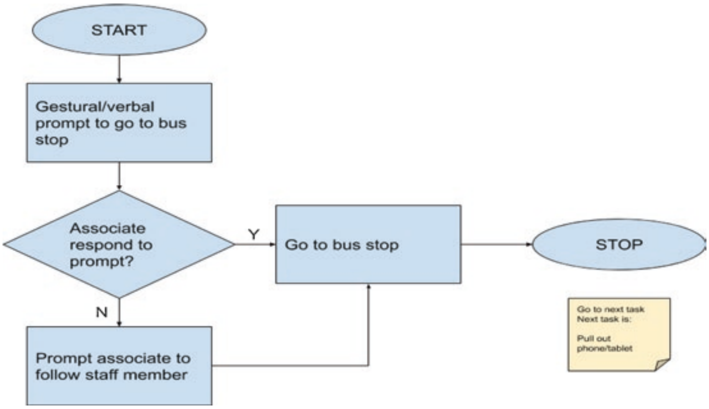

Fig. 5 Single activity as represented in the Virtuoso procedural task analysis highlighting ABA system of least prompts strategy

Fig. 6 Shuttle tracking application embedded in the virtual environment; an invisible player would trigger a shuttle model based on the information provided in this app

that was developed by using a non-playable character (NPC) and assigning a train model as that character's hat. When that character walked, it appeared that the train was moving. Borrowing from this, we attached a model of a university shuttle bus to an NPC as a hat attachment. We then used the built-in High Fidelity avatar recording tool to play a loop of the NPC. This process allowed us to create a functional shuttle route, but with limitations. The recorded NPC loops did not have physics or collisions, meaning that playable characters and in-world objects could pass through them. Given that road safety and socially appropriate behaviors related to catching the shuttle bus were pivotal to our intervention, it was therefore not suitable for a player to be able to walk into and through a shuttle bus that was driving along a route. Thus, we needed a different solution to simulate the shuttle bus.

Solving the shuttle bus problem required development of multiple scripts to handle the shuttle's movement and timing. We found a 3D elevator script that moved from point A to point B and modified it by hiding an invisible cube in the environment that we used as a trigger to initiate the shuttle's movement. When a player walked through the cube, it would load a JavaScript function and then activated the shuttle's movement. During usage testing, an administrator would control an invisible avatar, walk into the cube at a precise moment, and thereby activate the trigger. This would simulate a shuttle bus arriving on time, based upon that shuttle's location within a tracking application (Fig. 6). In this way, we were able to simulate a real-world activity, albeit not without significant complexity.

Discussion

As demonstrated through this case narrative, designing and developing a MUVE for adults with autism is a transitive, ill-defined, and complex problem-solving process, necessitating an interdisciplinary solution path. Our analysis of project methods and processes illustrates the requirements of broad skills and expertise spanning multiple disciplines. Clearly, creating a MUVE capable of promoting skills development and transfer is far more complex than merely ensuring some degree of photorealism. The experienced activity itself must reflect substantial similarity to the authenticity and realism of the real-world task upon which it is based. Realizing a single learning scenario in our functional VR prototype required years of development and continual problem-solving. The Virtuoso development team endeavored to use the best available evidence from the field in an attempt to realize the promise of VR for individuals with ASD. In the process of doing so, we were constantly confronted with the reality that a massive amount of effort is required to produce a learning scenario that is sufficiently realistic and authentic so as to instantiate identified design principles. For any team considering developing a MUVE for individuals with ASD, a reasonable question is whether to use commercial off-the-shelf software or to build something themselves. Unfortunately, there is no currently available off-the-shelf software on the market that allows the creation of MUVEs for individuals with ASD. Hence, it is likely that other developers in the field will undergo similar challenges.

Our hard-earned experiences serve as a poignant example of a tremendous research-to-practice gap in our field. In some ways, this gap is so daunting it could represent its own digital divide. The audacity, wherewithal, and interdisciplinary spirit required to forge a research agenda in this field are symptomatic of the significant – but not impregnable – barriers that researchers must address if we are to achieve the purported benefits of VR for individuals with ASD. Researchers tout VR as an exceptionally valuable technological tool that could significantly impact learning for people with autism (e.g., Parsons, 2016); however, the immense challenges of developing VR interventions for this population severely limit its feasibility and scale of impact. We hope that the examples provided here lend insight and guidance for those who wish to advance the current state of the art.

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Potentials of Teaching, Learning, and Design with Virtual Reality: An Interdisciplinary Thematic Analysis

Andrea Adams, Yonghua Feng, Juhong Christie Liu, and Eric Stauffer

Introduction

Virtual reality (VR), as a subset of immersive learning environments, may hold a yet-to-be-realized promise to enrich the context of teaching and learning and extend the capabilities of human cognition to new dimensions through expanded means of engagement. Recent advancements in consumer-ready devices with optical, sensory, and networked technology fostering close-to-real VR settings are promising for new learning experiences and access. Rapid developments in emerging hardware and software are creating a more feasible VR environment to enable formal and informal learning. As technologies evolve, frameworks for how we can apply instructional design to use these emerging technologies optimally, however, remain elusive (McGrath et al., 2018; Moro, Štromberga, & Stirling, 2017). As instructors, instructional designers, and other stakeholders in the educational process begin to experiment with the VR-enabled environments to solve instructional problems, it seems timely to revisit the VR learning experience in light of new technological developments.

VR is more recently defined as "use of immersive, highly visual, 3D characteristics to replicate real-life situations; typically incorporates physical or other interfaces such as a head-mounted display, motion sensors, or haptic devices in addition to computer keyboard, mouse, speech, and voice recognition. The user interacts as if it takes place in the real world, and the focus of the interaction remains in the digital environment" (McGrath et al., 2018, p. 187). These visual, sensory, and haptic

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features of the current and emerging VR environments indicate promises to provide a more precise representation of reality for learning, supporting learners to discover knowledge, and improving learners' motivation and attention in subjects such as information technology, engineering education, geometry, mathematics, and medical education (Alfalah, 2018; Alhalabi, 2016; Hwang & Hu, 2013; McGrath et al., 2018).

The integration of VR in teaching and learning becomes more affordable when these technologies become more readily available to the general public (Brown & Green, 2016). The documentation of the use of desktop-enabled immersive virtual simulation in teaching and learning practices is evident in the literature, as well as its impact on cognition and learning (Lee & Wong, 2014; Parong & Mayer, 2018). Studies have shown that VR environments create more engaging learning opportunities, enable interdisciplinary and collaborative participation, and enhance reflective thinking through the multisensory scaffolding of learning process (Hsu, 2011; Madathil et al., 2017; Monahan, McArdle, & Bertolotto, 2008; Oigara, 2018; Zhang, Jiang, Ordóñez de Pablos, Lytras, & Sun, 2017). VR has also been studied from perspectives of learning science, behavioral science, rehabilitation experiments, and its physiological implications (Annerstedt et al., 2013; Larson, Feigon, Gagliardo, & Dvorkin, 2014; Levinson, Weaver, Garside, McGinn, & Norman, 2007).

Although VR is deemed to be an additional avenue to reach students with its simulative and immersive attributes, research on the design and implementation of this medium in instruction needs systematic exploration (Georgieva, Craig, Pfaff, Neville, & Burchett, 2017; McGrath et al., 2018). Studies have revealed design-related questions surrounding VR, such as affordances and the lack of clarity on the pedagogy for VR use in educational contexts (Dalgarno & Lee, 2010; Fowler, 2015). Studies have also found areas that can be addressed with instructional design, such as cognitive overload, learning beyond routine skills, and learning with informed assessment and well-designed feedback mechanism (Andersen, Mikkelsen, Konge, Cayé-Thomasen, & Sørensen, 2016; Madathil et al., 2017; McGrath et al., 2018; Parong & Mayer, 2018).

Research Question and Research Method

These discovered challenges associated with VR in teaching, learning, and design indicate the value to pursue meaningful solutions. Therefore, the researchers of this project selected the educational design research as the methodology so that solutions can arise from the analysis and exploration of the existing literature (McKenney & Reeves, 2019). The project seeks to answer the question: How can instructional design help utilize the potentials of VR to enhance teaching and learning?

As a cornerstone component in design research, the literature review helps define instructional and non-instructional components problems that may enhance or hinder learning. Literature reviews can also provide worked examples with similar learning needs or resources for further exploration and design (McKenney &

Reeves, 2019). The unique complexity of cognitive load demand and fast-changing technologies in VR learning environments has also driven the search and analysis of VR-related literature to use the lens of human-computer interaction through teaching, learning, and supportive activities in a VR system (Lee & Wong, 2014; McGrath et al., 2018). Activity system (AS) has been adopted as a framework to analyze the teaching, learning, and design potentials of VR because of its systematic view to optimize the impact of technology in scaffolding human learning activities (Isssroff & Scanlon, 2002; Pea, 2004). Designing a learning environment needs to consider eight core components in an activity system: subject, rules, community, division of labor, tools and signs, mediated artifacts, object, and outcome (Engeström, 2001; Liu, 2018) (Fig. 1).

In a VR learning environment, *subject* concerns instructors and students; *rules* relate to expectations, regulations, learning assessment procedure, and guidelines such as guidebooks for using VR equipment safely and possibly concerning data privacy as well; *community* relates to the contexts, with VR environments as the specific context and social-cultural settings as the general context (such as institutional technology infrastructure); *division of labor* defines the roles of teacher, student, teaching assistant, VR lab manager, and organizational information technology infrastructure; *tools and signs* include the equipment and facility set up for a VR learning environment; *object(s)* includes student learning artifacts, research projects, and documentation of learning analytics in a VR system; *outcome(s)* includes the measures or standards of learning performance; and *mediated artifacts* are the visuals and interactive media conveying instructional meanings. As illustrated in

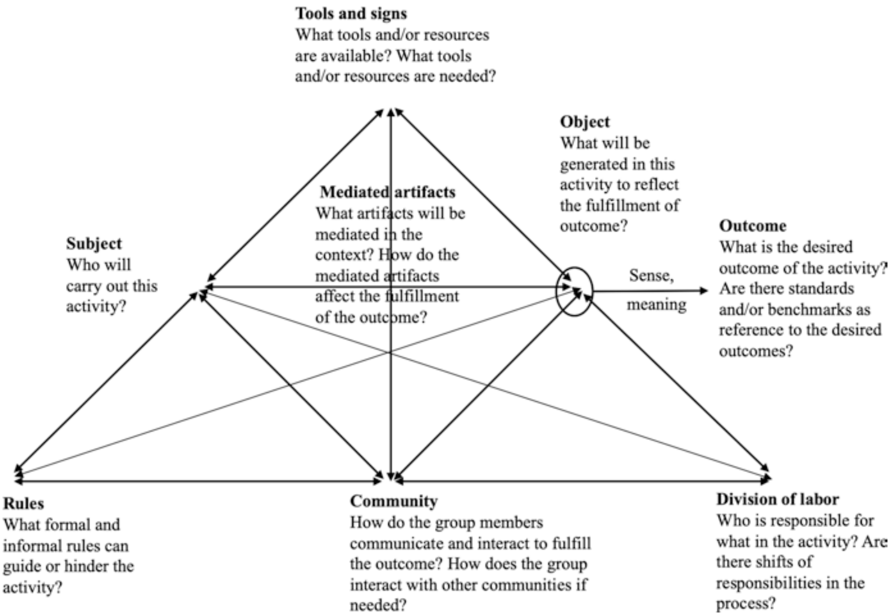

Fig. 1 VR learning environment: from an activity system perspective

Fig. 1, selecting, using, and creating useful *mediated artifacts* are critical in a VR learning environment.

An applied thematic analysis was performed toward the identified and synthesized literature to understand the functions of VR in teaching and learning and how design could provide enhancement (Guest, MacQueen, & Namey, 2011). First, a group of critical phrases was identified based on a general perusal of literature and research team members' teaching experiences, education design, and research expertise (McKenney & Reeves, 2019). The second phase included a systematic literature search performed in multidisciplinary areas. Thirdly, the research team prepared, organized, categorized, and synthesized the literature with themes and thematic keywords. Lastly, the researchers generated a report with contextualized interpretation (Elo & Kyngäs, 2008; Patton, 2005). In this study, the thematic analysis sufficed the analysis and exploration as part of design-based research of the emerging facilities and applications of VR (McKenney & Reeves, 2019). The results of the applied thematic analysis and design-based research included the recommendations of critical elements for the design of instruction and non-instruction components in a VR learning environment, the relationships of these elements, and the practical application of these elements for instructors and instructional designers.

Literature Search

The literature search started with key phrases collected through initial literature perusal and the researchers' expertise (McKenney & Reeves, 2019). The following key phrases were used as stand-alone search as well as various combined searches: "virtual reality," "online learning," "education," "cognitive," "activity system," and "instructional design." Also, the phrases of "science education," "simulation," "medical education," and "teaching" were utilized in the search to include multiple disciplines.

Several major scholarly search engines served the purpose of this research. EBSCOhost, Scopus, PsycNet, and Google Scholar all provided cross-database searches. The researchers limited the searches within peer-reviewed journals with the search engine filters. Since the focus of this research was on the application of new and emerging VR technologies in education, the publication search was limited to papers published after January 1, 2010, unless the citations were related to research methods, cognitive science, and human-computer interaction. The search also included literature with relevance to subject areas associated with the existing curriculum. The initial iteration of search resulted in a total of 179 published papers.

After the first synthesis of the literature, researchers performed a second filtering procedure categorizing all the selected papers with their corresponding journals and published keywords in a Microsoft Office spreadsheet. The sorting of the selected literature was performed based on journal relevance to teaching, learning, and design. After this secondary filtering, a third round of quick reading of the papers excluded irrelevant papers based on the following criteria:

1. The paper must include a research study on applications of virtual reality.
2. The paper must include findings related to education, learning, teaching, training, and instructional design.

After three iterations of literature search, filtering, screening, and selection, 34 papers were identified for the applied thematic analysis. The analysis was conducted with focus on the following components of an identified literature: (1) *research purpose*, including main focus, problem statement, or research hypothesis; (2) *research design and methods*, including research context, sample, and data collection methods; (3) *research scopes*, theoretical framework if there is any, and subject areas; (4) *VR technologies*; and (5) *key findings*.

Applied Thematic Analysis

An applied thematic analysis was conducted across the selected literature by combining coding keywords, themes, and subject areas of the 34 identified VR research papers in a Google Sheets workbook for collaborative identification of patterns and themes (Guest et al., 2011). The close review of these papers was based on the key structure of applied educational research (McKenney & Reeves, 2019). The researchers paraphrased the patterns of these research studies with coding guided by the applied key structure components of *main focus*, *subject area*, *and research methods and scope*, as synthesized below.

Main Focus The selected literature focused on several main themes, including the effective use of VR in instructional design, cognitive load when learning with VR environments, utilizing VR for knowledge and skill proficiency, and the use of VR to create effective collaboration and communication opportunities. Cognitive overload was discovered in the studies of learning with VR. Researchers also found that using multimedia learning principles and instructional design strategies to sequencing a smaller segment of VR simulation with feedback or reflective writing increased learning performance (Andersen et al., 2016; Andersen, Konge, Mikkelsen, Cayé-Thomasen, & Sørensen, 2017; Parong & Mayer, 2018). Studies also generated recommendations on utilizing instructional design to enhance the development of student self-assessment skills, provide automated assessment in VR settings, and facilitate techniques to enable reflective thinking (Andersen et al., 2017; McGrath et al., 2018; Zhang et al., 2017). Additional topics were reviewed and some did not align with the main themes but presented the comparison of two-dimensional and three-dimensional virtual learning opportunities (Passig, Tzuriel, & Eshel-Kedmi, 2016), as well as a review of pedagogies related to gender and VR (Makransky, Wismer, & Mayer, 2019).

Subject Areas The selected articles came from research in multidisciplinary areas and had a general focus on teaching and learning practice. For example, Parong and Mayer (2018) conducted two experiments within college biology class settings. One compared cognitive load, learning performance, and motivation between student viewing a PowerPoint presentation and a VR on blood cells working in the human body; the other compared student cognitive load and learning between viewing a whole length VR and interacting with a series of segmented VR. Following each segment, students wrote a reflective paper, which resulted in significantly better learning performance. Anderson et al. (Andersen et al., 2016; Andersen et al., 2017) used VR simulation to provide training to novice medical students on mastoidectomy. Dodd and Antonenko (2012) focused on the utilization of signaling to transition from a learning management system to a virtual reality activity in an online course. Fewer articles focused on specific disciplines. Some of the specific disciplines included studies or reviews of literature focused on physical education, science education, language learning, career and technical education, and educational tourism.

VR Technologies Virtual reality technologies are referred to in various ways throughout the selected literature. Terms that described VR technologies include virtual environments (VE), virtual learning environments (VLE), desktop 3D, head-mounted devices (HMD), and virtual worlds such as Second Life (http://secondlife.com). Even though there are many ways to describe VR, two commonly used VR environments are used to create and study interactive and immersive learning experiences. One is HMD, which provides the individuals experiencing VR to feel as if they were physically in the environment; and the other is desktop 3D, which is simulated through a computer monitor and does not immerse the individual's senses into the learning experience (Brown & Green, 2016; Moro et al., 2017; Parong & Mayer, 2018).

Research Design and Methods Research design and methods found throughout the selected literature primarily focused on applied research (Andersen et al., 2016; Andersen et al., 2017), literature reviews (Brown & Green, 2016; Fowler, 2015), and experiment or quasi-experiment research (Madathil et al., 2017; Parong & Mayer, 2018; Zhang et al., 2017). These literatures included a variety of frameworks and learning theories such as flow theory (Kartiko, Kavakli, & Cheng, 2010), cognitive theory of multimedia learning (Dodd & Antonenko, 2012), mediated learning experience (Passig et al., 2016), immersion concept (Fowler, 2015; Hedberg & Alexander, 1994), and constructivism (Huang, Rauch, & Liaw, 2010; Lee, Wong, & Fung, 2010). Multimedia learning principles, instructional design, and generative learning theory were studied through two experiments in the Parong and Mayer study (Parong & Mayer, 2018).

Practical Implications

Overall key findings from the selected literature indicate that virtual reality can be a useful learning tool. VR, as an enhanced multisensory simulation environment, can enhance student learning with the near-reality spatial, perceptual, and moving cognitive impact (Madathil et al., 2017; Moreno & Mayer, 2002). VR can provide opportunities for students to engage in creativity, active learning, communication, and group work. More importantly, the analysis has laid a research-based foundation for mapping practical implications of VR to teaching, learning, and design with the activity system framework (Fig. 1).

VR Related to Subject, Object Learning, and Learning Outcomes

Several barriers related to *subject(s)*, such as students and teachers, were identified in integrating VR in the learning experience. These included a need for higher-level technical skills for both students and instructors, cost of equipment and software, a high amount of development time, and possibly cybersickness. One critical finding related to the *subject* in a VR activity system and instructional design was cognitive overload in VR-enabled immersive learning in multiple studies (Andersen et al., 2016; Andersen et al., 2017; Parong & Mayer, 2018). Parong and Mayer (2018) were able to test the effects of integrating instructional design with multimedia learning principles to segment the VR scenarios with reflective writing prompts. Students in the second experiment in their study developed reflective writing (*object*) following interaction with a smaller segment of VR scenarios, which resulted in significantly better learning *outcomes* (Parong & Mayer, 2018). In medical training, studies found that VR simulations did help train student gain routine skills, until to a plateau; therefore, researchers suggested a stronger instructional design to help teaching, learning, and assessment practices in VR learning environments (Andersen et al., 2016; Andersen et al., 2017; McGrath et al., 2018).

Literature also indicates that VR enhances learning outcomes and creates an experiential learning experience, especially for learning instances that cannot be experienced by the learner or experiences that would otherwise be unsafe. Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis (2014) examined the effectiveness of virtual reality in the K-12 environment based on meta-analysis and also examined the effectiveness of virtual reality in higher education. The virtual reality technology analyzed in this research included three categories of games, simulations, and virtual worlds. A total of 67 empirical studies were included in the meta-analysis study. Among them, there were 13 studies on game-based teaching effects. Eight studies showed that game-based teaching could increase learning outcomes. There were 29 studies on simulation-based teaching effects, 18 of which showed that simulation-based teaching could increase learning outcomes. Twenty-five researches in this meta-analysis were reviewed on the teaching effect based on virtual worlds, and 17 of them showed that the teaching based on virtual worlds increased the learning effect. Based on the analysis, the researchers concluded that teaching based on games, simulations, and virtual worlds could have a positive impact on students' learning. The researchers also reached the conclusion that learning would be more effective when based on simulations and virtual world simulations that could assess student knowledge levels. When the simulation was used in practical course content, students learned better collaboratively than in independent mode.

VR-integrated learning would need alignment with learning theories and teaching principles (Madathil et al., 2017; McGrath et al., 2018; Merchant et al., 2014). For instance, the researchers in the Merchant et al. study (Merchant et al., 2014) found that if learners were repeatedly measured in a virtual world environment, they would reduce their learning motivation. Therefore, researchers suggested that teachers should consider incorporating instructional principles when integrating VR. Timed and segmented VR scenarios with assessment and feedback strategies were suggested based on these researches (McGrath et al., 2018; Moro et al., 2017).

As Tools and Mediated Artifacts for Spatial Learning in Science

Merchant et al. (2012) studied the effects of 3D desktop virtual reality environments on university student learning of chemistry. The study focused on detecting the effects of 3D virtual reality features on potentially selected perceptions and psychological variables of chemistry learning. The VR technology used in this research included a 3D desktop virtual reality environment with Second Life. With this VR technology, students observed and explored molecules in 3D space from multiple angles by rotating molecules, connecting atoms, or breaking atoms. The research participants were 238 undergraduates from a university in the United States, and the setting was an introductory chemistry course. This study focused on the content of the valence-shell electron pair repulsion theory in chemistry. The collected data included chemistry learning testing with Purdue visualization of rotations test and self-reported measures. In this study, students were given multiple opportunities to interact with a VR learning environment of the Second Life virtual world at various times of a semester. The research results showed that the 3D virtual reality environments could support the design of learning tasks, which could improve students' spatial learning ability and self-efficacy and improved students' learning.

Hammick and Lee (2014) investigated the effect of the 3D virtual world on an individual's communication experience. The technology used by researchers was also Second Life. This experiment used a 2x2 posttest-only group design, and the primary methods for collecting data were self-report questionnaires. The experimental participants were 58 undergraduates from a southeast university in the United States. The researchers conducted group discussions on the topic of drinking in the 3D virtual world (Second Life) and face-to-face environment and measured the individual's shyness, communication competence, communication apprehension, feeling of presence, and interactivity through questionnaires. The experiment results showed that the shy individuals had less communication apprehension in a 3D virtual world than face-to-face communication; 3D virtual world had less impact on individual behavioral intentions than face-to-face communication. Researchers suggested that communication for shy individuals in the 3D virtual world would feel more relaxed and comfortable, but the virtual world did not enhance their communication confidence and communication skills. Researchers interpreted that the main reason for the declined communication apprehension among shy individuals might be that the negative audiovisual cues in the virtual world were reduced. The reduction of audiovisual clues for communication in virtual reality was more difficult than face-to-face communication, and the powerful effect of communication in virtual reality was not as good as face-to-face communication. Also, the researchers also indicated that the elements of virtual reality on reducing the communication apprehension of shy individuals would need a full-scale study.

As Tools and Rules for the Learning Environment

Huang et al. (2010) introduced two cases based on virtual reality learning environment to promote the integration of VR in learning and to investigate learners' attitudes toward virtual reality. In the first case, the researchers introduced a web-based 3D VR interactive learning system designed for undergraduate medical students. The system was developed primarily with Autodesk 3ds Max, VR4MAX, for creating 3D course content. Based on this learning system, students could learn medical subject content and hold discussions with others. The participants were 190 college students. Based on the analysis of questionnaire data, the research result showed that immersion, interaction, and imagination in the virtual reality environment had a positive impact on improving students' ability to solve problems and on improving learning motivation. In the second case, the researchers introduced the 3D Human Organ Learning System and created a collaborative virtual reality learning environment based on this system. Through this system, students could learn independently or collaboratively. The researchers focused on collaborative learning involving multiple learners. The relationship between interaction, immersion, imagination, and collaborative learning was investigated through this phase of the study. The study participants were 76 students. Instructional design implications included that interaction could be improved with VR integration to incorporate the possibilities of learners' imagination in the immersive VR environment. The researchers also raised five issues that educators should consider when using a virtual reality-based environment:

1. What applicability of VR interface design could be integrated into a learning experience?
2. What technical challenges would educators encounter when using VR?
3. How should teachers clearly understand that a virtual world would not be equivalent to the real world in designing learning activities?
4. What cost factors should be considered when designing learning activities with VR?
5. The researchers emphasized that educators would need to explore the effectiveness of the VR learning environment further. As the authors note, all five of these issues should be incorporated into the instructional design process as VR is used to facilitate course content.

As Community for the Learning Environment and Implementation with Division of Labor

Lau and Lee (2015) focused their research on how to apply immersive and simulated virtual environments to enhance the learning experience of students. The research hypothesis was that the simulation-based learning environment was one of the factors that would foster students' creativity, and the simulated virtual environment would provide students with a sense of immersion. The simulated virtual platform used by the researchers was *ActiveWorlds*. The participants were eight university students. Researchers collected data by observing student interactions. The data included interactions between students and the environment, students' simulated emotional reality in the creative learning process, and interactions among students to understand their learning process, and students' reactions to the simulated virtual environment. Research results indicated that students spent 83.8% of their time on creative learning tasks, 16.2% of their time on social interactions, and that students' participation in the whole process was active. Students explored the use of avatars, but they did not use these avatars to express and communicate feelings. Students were curious and active in virtual reality environments, and they were excited about creative practice. Moreover, students especially liked the open areas in virtual space. The research findings showed that exploration and fun were essential parts of the virtual reality experience, and they were also important driving forces for creativity. Researchers believed that virtual reality promoted the expansion of teaching from simple tasks to complex skills. However, the simulated virtual environment could not replace the communication of the real world; the use of virtual reality could not be extended to physical reality. Therefore, researchers suggested that educators need to work together to explore appropriate and innovative educational methods to enable application functions of VR.

More and more resources in the form of time and money are being devoted to designing and developing desktop-based virtual reality instruction for teaching K-12 and higher education curriculum. Deploying desktop-based virtual reality instruction in schools and colleges not only involves financial cost but also the efforts to train the teachers to use them effectively as well as robust support of technology infrastructure. Therefore, it is critical that the *community* and *division of labor* are considered carefully in the instructional design and development of teaching and learning activities (Merchant et al., 2012).

Conclusion, Discussion, and Recommendations

VR has the potential to enhance teaching and learning in various disciplinary areas (Zhang et al., 2017). Along with the opportunities, these emerging learning environments also present challenges such as high cost, the complexity of management and support, and cognitive overload (Brown & Green, 2016; Merchant et al., 2012;

Parong & Mayer, 2018). There are also requests, based on research, of stronger instructional design and assessment strategies to effectively use VR learning environments (Andersen et al., 2016; Andersen et al., 2017; McGrath et al., 2018). Educational application of this unique type of emerging technologies needs to take a transdisciplinary perspective and integrate cognitive science with an understanding of complexity in design (McKenney & Reeves, 2019; Parong & Mayer, 2018). Instructors, learners, learning objectives, outcomes, learning content, VR scenes with respective messages and artifacts, and feedback constitute vital factors for the possible creation of an emerging learning activity system (Fig. 1). However, reservations on VR sickness, return on cost of facility, infrastructure setup, and physiological implications may hinder VR integration in teaching and learning.

Although the key findings suggest that VR may be a useful learning tool, practical factors continue to be significant barriers to adoption that may prevent the full realization of potentials for this type of technology with the purpose of instruction and without breakthroughs in the ability to develop and host instructional content. Contributing to this barrier is the lack of standardized VR platforms, or VR learning environments which are created for the express purpose of instruction. Generally speaking, current access to these VR learning environments is confined to a handful of platforms, and each needs its own proprietary hardware that uses the software often purchased through a third-party store. In some instances, VR experiences have been achieved with headsets that utilize smartphones as the conduit for the experiences, although the developmental or socioeconomic level of the student may, in many cases, create insurmountable barriers for its application.

The cost and availability are just physical factors preventing VR from fulfilling instructional values. At content level, educators are still exploring methods to create their own content like the more conventional multimedia of instructional video and digital interactive presentations. Many instructors will remain unsatisfied as they discover that the development of VR is beyond their technical skills and they lack of a background in the development of immersive and interactive VR settings. Currently, to develop VR content requires not only coding experience but, in many cases, a team of developers to create even simple learning experience in much less a full simulation. In some cases, faculty may be open to working in a more manageable form of VR, such as 360 photography or videography; but the interaction with the materials may seem, to some, as not too different from the interaction with 2D still images or video.

Hardware and content concerns aside, in a VR-facilitated learning environment, the decisions and choices made by teachers will be critically instrumental to the learning experience with strong integration of instructional design (Andersen et al., 2016; Andersen et al., 2017; McGrath et al., 2018; Parong & Mayer, 2018). As instructors conceptualize how students might construct meaning in VR in courses, a reimaging of interaction will be needed to scaffold experiences within an environment that offers a close-to-real immersive environment which allows learners to learn through interactions with virtual worlds, which may be otherwise impossible (Huang & Liaw, 2018). Feedback can imply merits as well as challenges with VR-enabled interactive mechanisms. The dialogue between instructor and learner or learner to learner constitutes the source of meaning creation in the immersive situation of VR. These all invite a reexamination of interaction within these environments.

The future infrastructure of VR-facilitated learning environment and related support can be designed from an activity system perspective. As illustrated in Fig. 1, VR facilitates immersive structure, perception, and experience based on *mediated artifacts* in a learning environment, which is an activity system (Engeström, 2000; Liu, 2018). There are *rules* and *division of labor* to be reformulated in a VR world, for instance, safety concerns in the physical environment because students are fully immersed in the VR space, potential neural and physiological impact to users, and alternative solutions to ensure ethical and inclusive applications (Moro et al., 2017; Patterson & Han, 2019). There are also forward-facing aspects related to *community* building and alignment with learning *outcomes*.

Future directions for research would be to enlist stakeholders to design with considerations of VR as an activity system (Fig. 1). In addition to discovering more affordable haptic multidimensional technologies, foci need to be geared toward investigating the content-specific skill and assessment with reflective learning in a VR environment (not only technical proficiency) and designing and building libraries or methods to share content and use these platforms, developing authoring tools to enhance efficiency in instructional design, and exploring alternative assessment and feedback mechanism in these VR environments. Collaborations between disciplines, such as those between educational institutions and entrepreneurial education, can also be considered as applied research to mutually benefit the teaching and learning on and off campus.

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Cultivating Design Thinking in an Interdisciplinary Collaborative Project-Based Learning Environment

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This chapter reports a case study of four interdisciplinary teams working on a learning space design, which helped us to examine how students' design thinking was developed in the ICPBL environment, what issues were involved over time within individuals and among team members, and how they overcame those challenges. We first reviewed the literature about interdisciplinary collaborative project-based learning (ICPBL) and design thinking, defining the terms and discussing the reciprocal relationships (Brown & Wyatt, 2010; Dym, Agogino, Eris, Frey, & Leifer, 2005; Jonassen, 1997), and mutual benefits between problem-based learning and design thinking (Ng, Yap, & Hoh, 2011; Skinner, Braunack-Mayer, & Winning, 2015). The literature review provided us with the theoretical framework to guide us to analyze the data and explore students' learning experiences and challenges, while developing their design thinking in the ICPBL environment. The findings revealed how interdisciplinary teams developed their design thinking in different stages in the ICPBL environment, which provide implications for research and instructional design.

Theoretical Frameworks

Collaborative Project-Based Learning

Project-based learning (PBL) is an instructional approach similar to problem-based learning (Savery, 2006) that has been used in medical education for decades (e.g., Barrows, 1986; Schmidt, 1983). In project-based learning, learning activities are

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organized around achieving a shared goal, such as completing a project (e.g., building a rocket, designing a website), with specifications provided for a desired end product (Blumenfeld et al., 1991). While working on a project, learners are bound to solve a series of problems toward attaining the goal. Like problem-based learning, an instructor's role is that of a coach, providing modeling, scaffolding, expert guidance, feedback, and suggestions to help learners successfully complete the final project.

In recent years, there has been a growing interest in studying interdisciplinary collaborative PBL. Interdisciplinary collaboration refers to an approach that consciously applies methodology and language from more than one discipline to examine a central theme or issue (Erkan, 2013). It is a process in which team members negotiate meaning, construct knowledge, and build consensus in a shared problem space (Roschelle & Teasley, 1995). Interdisciplinary collaborative PBL provides students with multiple perspectives, develops their critical thinking and innovative skills, fosters their self-confidence, and improves their communication skills with members of different disciplines (Erkan, 2013; Hmelo-Silver, 2004; Imafuku et al., 2014).

Design Thinking

Design thinking is an approach to learning that encompasses active problem-solving by engaging with and changing the world (Goldman et al., 2012). The design thinking process consists of three spaces: *inspiration*, *ideation*, and *implementation* (Brown & Wyatt, 2010). The inspiration space motivates the search for solutions which involves defining problems and identifying goals; the ideation space is the process when ideas are tested and solutions are developed and generated. The implementation space is the path that leads from the project stage into people's lives. Design thinking reflects the complex processes of inquiry and learning in which designers perform in a systems context, making decisions as they proceed, often working collaboratively on teams in a social process, and "speaking" several languages with each other (and to themselves) (Dym et al., 2005, pp.104).

In many ways design thinking shares similar characteristics with ill-structured problem-solving (Jonassen, 1997). Owen (2007) argued that design thinking has characteristics of great value to teams dealing with complex, ill-formed problems. It consists of two problem-solving activities, that is, constructing mental models and simulating them in order to draw conclusions and make decisions (Richmond, 2004). The first requirement of design is to understand the situation to be changed, which is problem representation based on the problem-solving literature (Jonassen, 1997). Design thinking requires designers to tolerate ambiguity, handling uncertainly, maintaining systems thinking and systems design (Dym et al., 2005), which is consistent with ill-structured problem-solving (Jonassen, 1997). However, different from PBL, design thinking, as a mode of inquiry, puts doing and innovating at the center of problem-solving, and it promises to address future needs of the globe. It has the potential to engage students in ways that are inclusive of their diverse thinking and makes school learning relevant and real, pressing local and global issues which can enhance one's motivation to learn (Goldman et al., 2012).

By improving students' design thinking skills, students will be more capable to face problems, think outside of the box, and come up with innovative solutions (Razzouk & Shute, 2012). Because design is a collaborative effort where the design process is spread among diverse participating stakeholders and competences (Bjögvinsson, Ehn, & Hillgren, 2012) and because design thinking requires designers to think as part of a team in a social process to engage in dialogues and communicate in several languages of design (Dym et al., 2005; Goldman et al., 2012), we believe that ICPBL intersects seamlessly with the design thinking approach to help students sharpen their problem-solving skills, which in turn facilitate the development of design thinking.

Purpose

Despite numerous benefits about design thinking well documented in the literature, there is little empirical research about how design thinking skills can be facilitated and developed in a collaborative project-based learnign environment. We assumed that PBL, which shares many characteristics with design thinking, could be an effective instructional strategy and approach to facilitate design thinking. Further, ICPBL, which provides students with multiple perspectives, could further strengthen design thinking. That said, we understood numerous challenges involved in ICPBL process. One of known challenges being the difficulty to communicate and negotiate meanings with other members, especially members from other disciplines, due to disciplinary differences, as noted by Imafuku et al. (2014). These differences made it difficult for individual members to make active contributions to a team project when topics of discussion are foreign to some members of an interdisciplinary team (Imafuku et al., 2014). Therefore, a case study (Creswell 2012) was conducted to explore the student design thinking experience in the ICPBL environment. Particularly, the following questions were investigated:

1. How do students develop design thinking in an interdisciplinary collaborative project-based learning (ICPBL) environment?
2. What benefits and challenges do students experience in the ICPBL environment, and how do they overcome those challenges?

Case Study

Twenty-five students from three disciplines (i.e., 9 from Interior Design, 8 from Architecture, and 8 Instructional Design and Technology) participated in a design project called *Innovative Learning Environment for 2025*. This project was sponsored by an architecture design company, which was intended to facilitate students' development of design thinking, problem-solving, and collaboration skills. Additionally, it was hoped that students could apply their knowledge and skills in educational setting to provide practical solutions and make an impact in education through redesigning learning space in schools.

The participating students were asked to create an innovative physical learning space for the year 2025, named "2025 Schools," to support active learning. The sponsor put a number of constraints to the project for the project teams, including the space capacity, which only allowed to accommodate 37 students, and a timeline of 6 weeks to complete the project. The students from the three disciplines self-selected themselves into four multidisciplinary teams (Team A, B, C, and D), each of which had similar number of members from each discipline. The teams were required to present their solutions (i.e., the artifacts of the prototype design) to their client (the sponsor of the project) after 6 weeks. In addition, seven faculty members from the three disciplines participated in this project as facilitators of the teams.

This case study was mainly based on the interview data, with reference to the other data sources, such as design documents, final presentation posters, and weekly progress reports. The interview questions asked the students about their ICPBL experiences regarding design thinking and problem-solving, including their collaboration, strategies, approaches, tools, challenges, and ways to overcome challenges. The design documents highlighted the features of solutions and rationales proposed by the teams. The posters and presentation documents were visual representations of teams' solutions for the innovative learning space for 2025. The individuals' progress reports provided detailed accounts of team collaborative design thinking processes and challenges they had encountered.

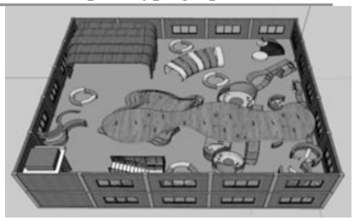
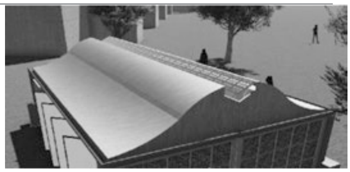
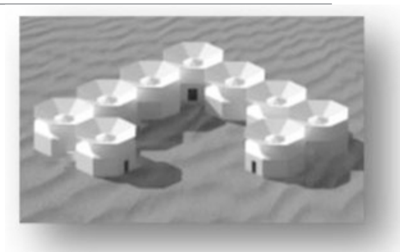
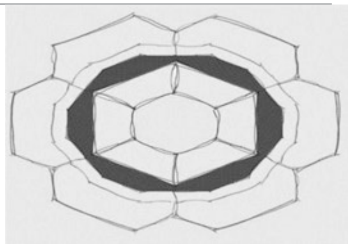
The interview data were coded and analyzed using an inductive approach (Le Compte & Preissle, 1993). Two researchers worked together to conduct the initial open coding, during which initial coding categories were generated and subsequently applied to code the design document as well as observation notes. As new data were gathered, initial codes were confirmed and modified. The researchers performed axial coding to draw relationships among the data. A quality check and data validation process were performed (Miles & Huberman, 1994).

Findings and Discussions

Develop Design Thinking in ICPBL

This collaborative project enabled interdisciplinary teams to go through various key stages of design thinking process that involved (1) the defining stage, during which problems and goals are defined and identified for the projects; (2) the ideation stage, during which solutions are generated and tested (Brown & Wyatt, 2010); and (3) the prototyping stage, when quick prototyping was developed (Brown & Wyatt, 2010). The design thinking process deepened learners' domain knowledge, shaped their understanding of needs and problems, and helped them to generate solutions to the problems related to their projects. Table 1 demonstrates the project description and prototypes developed by each of the four teams.

Table 1 Description of the four interdisciplinary team projects

Team	Design framework	Final product	Selected prototype graphic
Team A	An authentic learning environment	A learning hub that supports both individual and collaborative learning. It consists of seven functional units: studio, virtual room, library, group assembly, small group study area, individual compartment, and faculty area	
Team B	A sustainable model for growth: the pod garden	A mobile classroom of five trailers with the theme of gardening	
Team C	A student-centered, technology-rich constructive learning environment	Several pod-shaped buildings connected together to serve multiple purposes: an active learning center, a creative problem-solving center, and a community play center	
Team D	A four-centered learning environment (i.e., learner-centered, knowledge-centered, assessment-centered, and community-centered)	A large stretch-out complex, which is joined together by multiple hexagons. Each hexagon represents a module, within which there are three major components: a basic learning environment, an outdoor environment, and a 3D virtual reality laboratory. The basic learning environment can be adjusted into different configurations based on the needs, such as individual learning space, small group space, large group learning space, and a hands-on laboratory	

The Defining Stage After students self-selected themselves into different teams, they started to gather the information, analyze the core problems they had identified, and set goals for completing the project. However, it was observed that students of different disciplines exhibited differences in design thinking process and problem-solving approaches. The instructional design and technology (IDT) students would start the project by considering the clients' or learners' needs and conducting contextual analysis, whereas the students from architecture and interior design discipline started by discussing the design features of the learning space and the client's design requirements, such as sizes, storeys, materials, lighting, etc., to help them narrow down the scope of the project. As Wen from team D commented, the architecture and interior design students were more "practical," focusing more on the physical and structural aspects of the project, while the students from IDT were more "theoretical." Wen said:

> They [Architecture and Interior Design] are more practical. They focused on the functions of the learning space while we focused more on theoretical things, such as background information, problems, goals, target learners, and context in order to conduct needs analysis.

From Wen's response, it was clear that students from different discipline had different preferences in their design thinking approach. Although various stages of design thinking were considered as flexible and nonlinear, it seemed that IDT students tended to define the core problem well before moving to the ideation stage, while the students from architecture and interior design would rather start with ideation and then use the insight they had gained from the ideation stage to help them to refine their understanding of the problem.

The Ideation Stage After the problem representation in the defining stage, the core problem and subproblems became clearer. During the ideation stage, the team members started to generate ideas to find innovative solutions to the problems and then quickly moved to the next stage, that is, prototyping. Shan, a student from team D, stated that "we started to imagine what is going to happen in 2025, what were the needs for students, what would be some possible features for future learning spaces, and we brainstormed ideas to reach our goal."

> We shared our ideas with architecture and interior design students and they also gave us some ideas of what kind of space can meet the needs of high school learners that we seek to find out in this project… I think it was a special experience for me. Collaborating with the students from different colleges gave us lots of opportunities to reflect [on] our study. I have learned things like how to better understand their ideas from their perspective and how to explain my ideas in the language in which they can understand and how we can share our ideas under their specific condition to reach our shares goal. The better solution is to combine different prospective and collaborate.

This stage required disciplinary expertise to play a role. Due to different expertise and multiple domain spaces, the team members had to negotiate meanings, clarify ambiguity, and engage in the social co-construction process to gain a shared understanding of different disciplinary lingos. Lei, a student from team A, shared her experiences:

Based on Lei's experience, working with students from two different disciplines enabled them to see different perspectives, which triggered new thoughts. At the same time, students needed to learn to tolerate ambiguity, cope with the discomfort brought by members from the other disciplines, and communicate in language that could be understood by the other members. They also needed to learn how to handle the uncertainty and incorporate ideas shared by the members of other disciplines (Dym et al., 2005; Owen, 2007). All these communication, interpersonal, and problem-solving skills would facilitate the development of design thinking.

The Prototyping Stage In the prototyping stage, the teams evaluated different design solutions based on their goals and the information they had collected and generated during the defining stage and then negotiated meanings and reached a consensus to identify the best possible solution. For example, Shan told the researchers that their team had two design plans, and the team spent some time deciding which one would be more optimal and best support the users' needs. She said, "We had two solutions. We discuss about them. One solution was a curve one. It looks very nice, but it doesn't make good use of the spaces and not flexible, so we eliminated that plan." In the prototyping stage, ideas were further shaped through understanding, discussion, and reflection. In this process, the teams investigated the problem solutions and came up with optimal solutions. Admittedly, due to the time limitation, the teams did not go through the testing stage to evaluate their ideas rigorously.

Benefits, Challenges, and Solutions of ICPBL to Design Thinking

Benefits and Challenges The students believed that ICPBL was a "priceless," "knowledgeable," but challenging experience due to domain differences and language barriers that resulted from disciplinary differences. Jane from team B said:

> My experience was, unfortunately, knowledgeable but unsuccessful. I enjoyed working with both education students very much but felt maybe the language barrier made some aspects more difficult. However, they were always prepared and ready to work and really put forth a wonderful effort, making our job as designers much easier. Evidence and research based design is crucial to the success of a project and without our education team, our design would have lacked clear direction.

Jane was aware of the expertise that IDT student shared with the team, which helped her to have a better understanding of design thinking; for instance, exceptional designs do not just come from ideation, they need to have very solid theoretical bases. However, at the same time, her team experienced challenges in communication, which made their experience unsuccessful.

Yun also commented on challenges of the different terminologies:

> They talk about things we are not really familiar with, and we talk about things, sometimes we use some educational terms, so they're kind of confused about what we are talking about. So we need to explain what this term really means and they need time to figure out what we are talking about and sometimes I'm confused about what they are talking. We spent a lot of time trying to understand each other.

Based on students' experiences, it seems that domain differences and associated different terminologies undermined teams' communication, thus affecting effective collaboration and design thinking processes.

Students experience not only challenges in communication but also challenges in design approaches, especially at the beginning. Yun commented:

> We focused on totally different things and I felt like they'd like to have [work on] the design idea because they don't have any educational theory background, so they like to have a big picture about their design [yet it was] without any educational support. But for us we'd like to provide the background of what happened to current education and it gives them some support to have them develop their ideas. So it's hard for us to compromise.

It seemed that initially students from different disciplines tended to choose different design approaches to deal with the same problem, which made it challenging for them to understand and work together with each other, thus impacting the team design thinking process.

Technologies in Supporting Design Thinking Luckily, the teams seemed to figure out ways to use technology to resolve their communication challenges and facilitate the team discussion, thus promoting the development of design thinking. For example, tools like *SketchUp* were found to help visually represent individuals' ideas, which provided a basis for the team members to understand each other and supported their subsequent meaning negotiation and knowledge co-construction. Lei responded:

> The architecture and interior design students used Sketchup to make visualization of the design, which helped us a lot to understand their design cause. At the beginning if you haven't studied like the engineering parts, you have no idea what they are talking about. This visualization tool help us a lot when we have meetings and discussions.

Similarly, Yun found that SketchUp really help them "brainstorm" and express their ideas.

The socially sharing tools, such as Google Drive and Dropbox, were used by team members to co-author documents. Wen stated: "We used Dropbox where we submitted our individual work and if we have our own ideas or something like that, we will write them down and submit to Dropbox for sharing." This tool helped the other team members to share their perspectives and provide feedback more easily. Therefore, technology was used as a knowledge extension and construction tool in this case.

Based on students' responses, it seemed that technology played a larger role in helping team members understand each other during the process of generating and developing ideas, thus supporting them to move through the ideation and prototyping stages, acquire skills, recognize patterns, and construct ideas (Brown & Katz, 2011; Brown & Wyatt, 2010), which were essential to the development of design thinking.

Conclusion

This case study shows interesting intersections between design thinking and ICPBL across three different design disciplines. Although the three design disciplines shared numerous similarities, such as critical and creative thinking, communication skills, needs analysis, planning, and designing, they also possessed specific features that were unique to a discipline. The commonalities among the three disciplines helped to enhance students' design thinking and creative problem-solving, while the differences allowed them to see multiple perspectives from different aspects of design. However, the disciplinary differences also presented challenges when the team members tried to reach understanding to create a shared problem space. As such, scaffolding strategies and tools are essential to facilitate a successful and productive ICPBL experience to promote the development of design thinking. In an ICPBL environment, students design to learn and learn to design, which adds value to the ICPBL and design thinking research.

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Reframing Interdisciplinarity Toward Equity and Inclusion

Amy C. Bradshaw

Reframing Interdisciplinarity Toward Equity and Inclusion

For those of us working in instructional design and technology (IDT) and the learning sciences (LS), there is a near-instant attraction and perceived relevance to the term *interdisciplinary*. Instructional designers prepare instruction and training for a vast array of diverse disciplines and domains, including those for which the designers have no prior personal knowledge and experience, and members of the learning sciences can claim interdisciplinarity – or at least multi-disciplinarity – as one of the key elements of the very definition of the field. But is it necessarily so that either we or our fields are inherently interdisciplinary? What does the term mean, and how do we apply it in practice? These are important questions because how we define the term *interdisciplinary* influences how we engage it, and how we engage the term *interdisciplinary* reinforces how we define it.

Interdisciplinary work integrates knowledge, methods, and perspectives from different disciplines, using a synthesis of approaches, with valuable contributions emerging through the combination of disciplines, as well as at the intersections between the disciplines. Seeking, including, and considering multiple diverse perspectives around a problem or project can facilitate fuller, richer meaning-making; better problem identification and articulation; more complete and accurate identification of benefits, limitations, and potential harms; and more innovative problem-solving. But how do we determine the appropriate mix of perspectives, knowledge, and methods for particular contexts? That question is the focus of *interdisciplinarity,* the "analytically reflective study of the methodological, theoretical, and institutional implications of implementing interdisciplinary approaches to teaching and research" (Miller, 2017, p. 1). Under the umbrella of interdisciplinarity, different

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terms have been used to describe a variety of configurations, which Miller summarized as follows:

> *Multidisciplinary* approaches involve the simple act of juxtaposing parts of several conventional disciplines in an effort to get a broader understanding of some common theme or problem. *Cross-disciplinary*approaches involve real interaction across the conventional disciplines, though the extent of communication and thus combination, synthesis, or integration of concepts and/or methods varies considerably. *Transdisciplinary*approaches, meanwhile, involve articulated conceptual frameworks that seek to transcend the more limited worldviews of the specialized conventional disciplines. (p. 1, italics added)

Categorizing projects, practices, and modes of engagement according to these more specific terms provides opportunities to reconsider our own practices and reflect on how and what we are engaging under these labels, and also how we might improve our engagements and their outcomes. Taken to an extreme, contrasting all the different ways these subterms have been defined and implemented, and making assertions about what is *truly* interdisciplinary among them, may lead to hair splitting, nuancing, and in the worst case, an imposed standardization model. That is, overindulging in definition articulation and categorization may constitute a paradox of *disciplining interdisciplinarity* – effectively turning interdisciplinarity itself into a discipline.

However, more concerning than the potential interdisciplinary paradox – and the purpose of raising the issue of labels and definitions in this chapter at all – is that, despite what at first glance appears to be many choices and configurations, the variety of categories and terms mentioned above collectively reinforces a singular epistemological assertion. The implicit epistemological assertion is that knowledge and knowledge production are properly (and perhaps exclusively) engaged via mechanistic and instrumental means, such as by "juxtaposing parts" and through "combination, synthesis, or integration" (from Miller's quote, above). Without thoughtful and intentional troubling of that epistemic assertion, we effectively *reproduce* mechanistic framings, as well as their associated tendencies and practices. How does implicit mechanistic framing enable and constrain our work in IDT and the learning sciences? The aim of this chapter is to facilitate reflection on the limitations and ramifications of the epistemological and practical framings we intentionally or unwittingly invoke related to interdisciplinarity and its associated terminology and how these issues relate to pursuit of equity and inclusion.

Dominant Framing

Interdisciplinary approaches tend to be most frequently presented and engaged as one-off projects, motivated by recognition that a problem or project in a particular context cannot be adequately addressed from within a single discipline (Klein, 1990). The dominant framing of interdisciplinary work is that it is a sometimes necessary response to disciplinary work (Choi & Pak, 2006; Miller, 2017) and that the dichotomous relationship of disciplinary and interdisciplinary work is a result of a long-ago fracturing of knowledge into distinct disciplines. With disciplinary work conceived as one piece of the larger whole of knowledge, interdisciplinary work is frequently viewed as putting the pieces – or at least some of them – back together to make a bigger picture. This common framing of interdisciplinary work as a reconstituting process necessitated by disciplinary separation frequently results in conceptualizing *learning* as a pursuit of objectified content, which can be transferred, controlled, and manipulated. This is an *instrumentalist* approach that limits our abilities to recognize and articulate problems, including how to approach interdisciplinarity itself.

Instrumentalist approaches to interdisciplinarity are consistent with content delivery modes of teaching and learning, which Freire (1970) rejected as *banking*. He called on educators to "abandon the educational goal of deposit-making and replace it with the posing of the problems of human beings in their relations with the world" (p. 79). The tendency toward instrumentalism is exacerbated by commonly encountered external motivations for engaging interdisciplinary work, such as forming interdisciplinary teams for the purpose of meeting requirements in grant proposals, using the term to justify working with particular friends or colleagues in other disciplines, seeking opportunities for academic publications or paid consulting work, and so forth. The prioritizing of instrumentalist motivations for engaging interdisciplinary work limits the likelihood of meaningful engagement across philosophical divides, which, if pursued, could help facilitate exposure and questioning of underlying assumptions and blind spots. For this reason, it is important to reconsider our framing of interdisciplinary work and to distinguish between mechanistic contrivances designed to be just sufficiently interdisciplinary to serve an instrumentalist priority and intentionally balanced critical partnerships that overtly value more than the predefined outcomes of such partnerships. There is value in and need for attention to cultivating practices for deep engagement with diverse views, perspectives, and lived experiences in our efforts to develop solutions to particular problems in specific contexts.

An example of an instrumentalist type of partnership might involve STEM discipline personnel driving a large-scale educational project, with non-STEM discipline representatives serving only limited, predefined functions – for instance, partners from education being included only for the purpose of conducting a summative evaluation after the project's educational process has already been solidified. The full potential benefit of working collaboratively with partners in education is neither considered nor pursued because the underlying purpose of the partnership serves an instrumentalist aim, such as meeting requirement for acquiring external funding. Barthes (1972) rejected such approaches, stating, "In order to do interdisciplinary work, it is not enough to take a 'subject' (a theme) and to arrange two or three sciences around it. Interdisciplinary study consists of creating a new object, which belongs to no one" (p. 72). Others have similarly recognized and cautioned against these approaches: "Interdisciplinary studies in education must move beyond a simplistic conceptualization in order to carefully address the set of relationships at play throughout the planning, data collection, analysis, and dissemination" (CohenMiller, Faucher, Hernández-Torrano, & Brown Hajdukova, 2017, p. 296).

The term *interdisciplinary* also may be used as a legitimizing signifier that allows projects to function – intentionally or not – as tools of appropriation, colonization, cultural invasion, or disciplinary eradication. Penny (2009) also recognized this danger:

> There is a simplistic assumption abroad that to practice interdisciplinarity, one can simply drag the methodology or subject matter from an outlying discipline into one's own (with a click of the mouse, as it were). In its most cynical and unenlightened forms, such a process is inherently imperializing and retains an unreconstructed disciplinary hubris. It retains the master discourse status of the "home discipline," and is thus unable to recognize that in the process of uprooting the products of the outlying discipline and bringing them "indoors," they might in the process wither and die, transformed and reduced like bleached specimens preserved in formalin (p. 35).

This practice is conducive to the loss of potential benefits in any case but is urgently dangerous in contexts where projects and their outcomes have life and death implications, such as related to human migration, environmental sustainability, and species eradication. In both thought and practice, the dominant framing reflects a mechanistic and instrumentalist epistemological orientation. Are there other framings for considering and engaging interdisciplinary work that are more beneficial for projects with sociocultural axiological priorities such as equity and inclusion?

Alternative Framings

Narrow Versus Wide

Kelly (1996) contrasted the instrumentalist approach common in the sciences, with more humanistic approaches involving meaning-making, the need for an identity, intersubjectivity, self-respect, interpersonal relationships, and self-expression, and described these two distinct approaches as being separated by a "deep epistemological fissure" (pp. 96–7). He used a horizontal spatial metaphor contrasting the terms *narrow* and *wide* to alternatively frame two general approaches to interdisciplinary work. *Narrow* refers to interdisciplinary approaches that stay within their own general epistemic boundaries of either instrumentalist material manipulation, or humanistic meaning-making. Both of the following examples represent narrow interdisciplinary collaboration: (a) geologists partnering with chemists and (b) sociologists partnering with anthropologists. In example "a," both disciplines are predominantly *instrumentalist*, and in example "b," both disciplines are predominantly *humanist*.

In contrast, *wide* interdisciplinary approaches require epistemic negotiation between and among both instrumentalist and humanistic approaches, in order to come to a shared and more comprehensive understanding of needs and appropriate actions that should be taken in response to those needs. Merely borrowing content from a discipline on the other side of the epistemological gap is not sufficient to move beyond a narrow interdisciplinary approach. Wide interdisciplinary approaches require a careful look at "the often covert epistemic tension that exists between the sciences and the humanities" (p. 99). Epistemological underpinnings and tensions warrant consideration in the context of the instructional design and technology field, specifically. IDT programs are often situated in colleges of education or elsewhere in the social sciences – which are bgenerally considered to be humanist, meaning-making disciplines. However, the IDT field's technical and technological roots and historical and continuing tendencies toward *scientization* contribute to its general epistemic emphases on manipulatory control of knowledge as content (Bradshaw, 2017, 2018a). As a general field, IDT tends to be more epistemologically similar to STEM disciplines than to the more sociology- and humanist- focused subfields within education, such as curriculum theory or educational studies. Moreover, as members of our field are increasingly responsible for engaging and guiding instructional development across multiple disciplines on both sides of the epistemological gap, it is crucial that we more directly acknowledge and engage the epistemological tensions underlying our work. This will require the mainstream of the IDT field to transform curricula and academic preparation for research and practice to more directly and consistently support deep philosophical engagement with issues at the intersection of culture, learning, and technology (see Bradshaw, 2017).

Shallow Versus Deep

Where the *narrow* versus *wide* interdisciplinarity framing summarized above uses a horizontal metaphor related to bridging epistemological chasms, a *shallow* versus *deep* framing invokes a vertical metaphor. *Shallow* interdisciplinarity does not require acknowledgment of underlying philosophical assumptions among the partnering domains. Even partnerships involving fields on opposite sides of the epistemological chasm can reflect shallow interdisciplinarity when contributions to the project are primarily content based or when contributing partners simply conform to the dominant epistemological assumptions of the primary organizing partner.

In contrast, *deep* interdisciplinarity requires identification, questioning, and negotiation of implicit underlying philosophical orientations and assumptions: *ontological* (What is the nature of reality?), *epistemological* (How can reality be known?), *axiological* (What values do we prioritize?), and *methodological* (How do we go about answering the previous three questions?). Deep interdisciplinarity demands more than simply "poaching" subject matter or techniques from another discipline or collaboration between two related subdisciplines but instead involves "willingness to reflexively consider the assumptions of one's own field from an external viewpoint, to interrogate the values underlying the methodologies and techniques of one's own discipline" (Penny, 2009, p. 41). To do this, deep interdisciplinary engagement also requires the psychological aptitudes of:

- *Humility* – in the recognition that value assumptions of other disciplines are as valid/arbitrary/contingent as one's own and in the ability to admit that one does not know
- *Intellectual rigor* – to negotiate epistemological and ontological challenges
- *Courage* – to relativize one's own commitments, to deal with anger from those whose world view you will destabilize, and to challenge the organization and power structure of the academy. (Penny, 2009, pp. 39–40)

Deep interdisciplinarity shares many important characteristics with critical pedagogy – a sociopolitical educational approach focused on empowering learners and transforming systems and structures that contribute to oppression and marginalization. Both involve a critical form of *praxis* (transformation toward justice, through naming, critical engagement, and reflective action). Similarly, characteristics and tendencies of shallow interdisciplinarity align closely with transmissive, or *banking,* approaches to education. The contrasts between transmissive and transformative educational approaches parallel the contrasts between instrumental and critical approaches to interdisciplinarity. The connections and resonances between deep interdisciplinarity and critical pedagogy have been noted elsewhere in existing literature. For example, McClellan and Johnson (2014) noted that "deep interdisciplinarity celebrates the complexity and dedication critical pedagogy requires while simultaneously encouraging both instructors and students alike to see the world in altogether new ways" (p. 6). They called on critical pedagogues "to rethink their relationship(s) to interdisciplinary knowledge and for instructors of interdisciplinary classrooms to rethink their relationships to critical pedagogy" (p. 5):

> While interdisciplinary course development is a complex epistemological, ontological, and axiological endeavor, deep interdisciplinarity provides what we see to be an adaptable framework for embracing critically-reflective directions of possibility for interdisciplinary teaching and learning (McClellan & Johnson, 2014, p. 9).

Instrumental Versus Critical

Perhaps the most direct framing of interdisciplinarity in relation to human problems and purposes is an *instrumental* versus *critical* comparison. *Critical* interdisciplinarity encompasses the assumptions and priorities of both *wide* and *deep* interdisciplinarity. Critical interdisciplinarity is *wide* in the sense that epistemological assumptions and dominations must be acknowledged and negotiated by partners with different dominating epistemological stances, who come together as equals on projects that are to be defined and pursued collaboratively – via the collaborative engagement process itself. Dialectically engaging and understanding each other's epistemological perspectives and pressures are necessary and in high contrast to working for a predetermined, often narrowly defined, outcome, accomplished via dominance of one partner's epistemological orientation over the other(s). Critical interdisciplinarity is also *deep* in the sense that, in addition to directly engaging epistemological and other philosophical underpinnings and assumptions, the team specifically attends to issues of cultural and positional power, individual and systemic barriers to access and equity, and potential connections between the project at hand and other human needs and possibilities. Critical interdisciplinarity does not simply *allow* for engagement with people, structures, and issues beyond the walls of academia: it *requires* it. As described by Frodeman and Michaum (2007), critical interdisciplinarity extends not only across the epistemic gap but also beyond academic settings into public, private, and community sectors:

> Critical interdisciplinarity requires a horizontal and vertical axis. The contemporary knowledge society represents a multi-dimensional challenge, involving not only the horizontal axis that stretches across the physical sciences, social sciences, and humanities, but also a vertical axis where academic research is self-consciously integrated into the multiple contexts of contemporary life. (p. 513)

While the framings and constructs discussed to this point are not precisely synonymous and interchangeable, there are resonances among them. Using an instrumental versus critical framing as an organizing structure, the previously referenced framings and their general attributes and tendencies are loosely related as presented in Fig. 1.

More Instrumental ⟵	⟶ **More Critical**
Analogous Framings	**Analogous Framings**
Shallow	Deep
Narrow	Wide
Related Attributes and Tendencies	**Related Attributes and Tendencies**
More mechanistic	More humanistic
More reductionist	More holistic
More replicative	More transformational
More positivist	More interpretivist
More predetermined and procedural	More open and evolving
Banking approach to teaching and learning	Problem posing approach to teaching and learning
Domination of empirical methods, regardless of context or purpose	Dialectical engagement, negotiation and inclusion of multiple methods, particular to context
More likelihood of importing or annexing content	Engaging content via its original cultural and philosophical context
Silencing or ignoring of voices that challenge assumptions	Hearing and understanding voices that challenge assumptions

Fig. 1 Instrumental versus critical interdisciplinarity, framings, attributes, and tendencies

Beyond Content: Toward Equity and Inclusion

Framing Influences Engagement

The ways we think about and engage interdisciplinarity lead to different modes of interaction with others, and different ways of monitoring and regulating our own thoughts, emotions, assumptions, and actions. Consciously or not, we impose our framings and priorities on all aspects of interdisciplinary projects from the earliest phases of seeking information and potential project partners to problem articulation and choosing or developing approaches for collaborative inquiry and problem-solving. Shallow, narrow, instrumentalist forms of interdisciplinary engagement may be perceived as the right way to approach interdisciplinarity, based on nothing more than their familiarity as a dominant mode of engagement in our field. Our failure to recognize and question assumptions of rightness rooted in familiarity may result in our neglecting or rejecting consideration of framings and practices that might better facilitate inclusive decision-making. Human decency should be reason enough to prioritize equity and inclusion in our academic and professional work, but there also is substantial evidence that equitable and inclusive environments improve learning outcomes for all participants, not just the most marginalized (Antonio et al., 2004; Gurin, Dey, Hurtado, & Gurin, 2002; Hurtado, Dey, Gurin, & Gurin, 2003; Milem, 2003; Milem & Hakuta, 2000). Equitable and inclusive environments also lead to enhanced cognitive complexity in problem-solving, and increased innovation in problem-solving in team environments (Page, 2007, 2010). Although these results are among the frequently stated or assumed goals of interdisciplinary engagement, many interdisciplinary projects fall short of achieving them. Pursuing equity and inclusion must be prioritized in all our academic and professional work and attending to issues of power, equity, and inclusion is particularly important in interdisciplinary contexts.

Different framings for interdisciplinary engagement might lead us to different responses to and openness regarding questioning and negotiation, awareness and mitigation of potentially harmful or limiting team dynamics such as the silencing of divergent views, and commitment to dialectical and supportive engagement despite differences in perspectives and priorities. Typically cited benefits of engaging interdisciplinarity (e.g., critical thinking, innovative problem-solving) may not equally manifest from all types of interdisciplinary engagement. Narrow, shallow, and instrumental approaches do not explicitly require attention to dynamics of power and positionality at either individual or structural levels. Deep and critical interdisciplinarity supports development of practices and dispositions that are more conducive to recognizing and openly discussing structural and positional barriers to equity and inclusion, even when that is not the expressly stated goal of a project. Developing critical humility, supporting openness and trust among partners and stakeholders more broadly, and valuing different perspectives and perceptions, for example, are not only beneficial outcomes of critical interdisciplinarity; they are some of the very processes and practices through which it is engaged.

Prioritizing Efficiency Has Consequences

The general tendency in IDT and LS of prioritizing efficiency contributes to the domination of instrumental expressions of interdisciplinarity and also limits and interferes with development of deeply critical forms and expressions of interdisciplinarity. To put it simply, instrumentalist approaches are not adequate for sociocultural contexts where equity, inclusion, and belonging are recognized as desirable outcomes because a byproduct of prioritizing efficiency is reproduction of the dominant social systems, which includes deeply embedded injustices. Dominant practices normalize and reproduce inability or unwillingness to see beyond mainstream practices and perspectives. Even where there is sincere desire to be equitable and inclusive in our personal practices, some of us are insulated by our positionalities, social conditioning, and prior experiences from having to learn about these issues sufficiently to engage equitably and inclusively, let alone teach others to do so. The general lack of open and critical discussion of these issues allows perpetuation of (wrong) assumptions that inequity, exclusion, and discrimination are merely individual choices and characteristics, and not systemically-entrenched features of our dominant culture. For those of us who have not been consistently and historically on the receiving end of systemic injustice, the learning curve related to its forms and means can be steep. Because our field tends strongly toward instrumentalism, while diversity, equity, and inclusion are more humanist concerns, our epistemological assumptions need to be troubled and thoughtfully negotiated. This requires an interdisciplinary framing that acknowledges the epistemological chasm between instrumentalist- and humanist-oriented disciplines and practices, and willingness of all partners to reflect on their own epistemological preferences and limitations.

Declarative Knowledge Is Insufficient

Scholars and practitioners of IDT and LS are increasingly recognizing the need to understand and address issues of equity and inclusion at both individual and structural levels, but moving beyond declarative phases of engagement will remain challenging unless structural supports for increasing knowledge and competency of scholars and practioners themselves in this area gains adequate traction in the mainstream. As more among the mainstreams of our fields understand the urgency to address these concerns in our academic work and professional preparation, many feel inspired to develop training materials and environments for this purpose, and to do so quickly. It is crucial that such projects be engaged through collaboration with experts in the topic via critical interdisciplinary approaches, rather than instrumental ones, in order to mitigate our dominant tendencies toward prioritizing efficiency. Critical interdisciplinary projects can provide us with opportunities to engage with and receive mentoring from experts regarding the multidimensional needs and challenges inherent in this work. Such collaborations must be critical in both outcome and means. Declarative levels of understanding and instrumentalist approaches to interdisciplinarity will never be sufficient to disrupt structural inequities embedded in our social systems and academic institutions because injustices and inequities are complex and multifaceted, involving cognitive, affective, and attitudinal domains, which are further complicated by conditioning from the dominant culture that we should avoid disagreement and even differences of opinion.

Transformation Involves Conflict and Disruption

Equity and inclusion do not happen by accident. They must be intentionally and collaboratively pursued – not only sometimes and not only in ways that are familiar and convenient. Working toward equity and inclusion necessarily conflicts with the dominating (false) narrative of social neutrality (Bradshaw, 2018b) and disrupts the norms of the dominant culture. This can result in uncertainty and discomfort for those who have historically benefited from systemic injustices, who may try to discredit work toward equity and inclusion by labeling it "political." But through a critical lens, we see that social spaces and standardized practices are never *not* political. Social and institutional systems are continuously politicized through obfuscation and mystification of the ways systemic injustice operates and is maintained. Calling efforts toward equity and inclusion political is communicating a strong preference for the inequities and abuses of the current system to continue.

Critical approaches value honesty and authentic discourse, which bring to light different perspectives, values, and needs – and, in the process, illuminate conflict. Conflict is a byproduct of functional and authentic relationships that enables fuller and deeper understanding, and is necessary for growth and transformation. Willingness to name, critically engage, and courageously transform conflict is an important distinguishing feature of critical approaches. In contrast, instrumental approaches prioritize efficiency and produce tendencies of conflict avoidance, which impedes efforts to transform injustice. If we want social transformation toward equity and inclusion, a purely instrumental approach will not do.

Labels Don't Capture the Complexities

Although the grouping presented in Fig. 1 is useful for considering our goals and assumptions about interdisciplinarity, instrumental and critical approaches to interdisciplinarity are not always mutually exclusive in practice. Some aspects of intentionally critical projects might be engaged in mechanistic ways that might work against the project's own goals. External pressures and interpersonal dynamics consistent with critical and instrumental approaches can be happening at the same time, in the same project, and even with same individuals. Engaging critical interdisciplinarity is a *practice*. Developing trusting and supportive relationships across differences in philosophical stance, professional and academic focus, positionality, and lived experiences through dialectical engagement helps ensure issues are understood and considered from many perspectives. This is a beneficial practice in interdisciplinary projects, as well as in the rest of our lives. Personal perspectives and insights that can help inform and alter perceptions about projects are more easily shared when we are practicing critical humility and active listening, for example, among other practices associated with critical approaches.

We can be strong in our disciplines yet have severe blind spots where equity and inclusion are concerned, and we cannot assume collaborative partners will necessarily be experts on issues of equity and inclusion. We need people with that expertise to be at the table. However, putting that responsibility only on people who are historically marginalized by our systems is inequitable, too. Seeking ongoing and intentional learning about issues of justice and inclusion, with humility and willingness to learn from mistakes, is needed from all partners. In closing this chapter, several points bear repeating:

- Equitable and inclusive environments improve innovative problem-solving.
- Equity and inclusion do not happen by accident.
- Instrumental interdisciplinarity is counterproductive to goals of equity and inclusion because the inherent prioritizing of efficiency reproduces status quo injustices.
- Although critical interdisciplinarity is more conducive to the development of equitable and inclusive engagement and outcomes, further individual and collective learning is still needed.
- Projects for which equity and inclusion are an explicit goal demand critical interdisciplinarity. If equity and inclusion are sincerely desired outcomes, they must also be the means of pursuing those outcomes.
- If we are not working intentionally and critically toward equity and inclusion, our work reinforces the status quo. If we are only interested in equity and inclusion *sometimes*, we are probably *mostly* reinforcing current inequities.

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Interdisciplinary Development of Geoscience OER: Formative Evaluation and Project Management for Instructional Design

Juhong Christie Liu, Elizabeth A. Johnson, and Jin Mao

Introduction

Learning through laboratory method classes with access to lab equipment and quality instructional materials has remained a core effective approach to science education for decades (Hofstein & Lunetta, 2004). However, the lack of appropriate instructional materials and resources and limited access to research equipment present significant barriers to learning the concepts, procedures, and analytical skills that students must acquire to succeed in science, technology, engineering, and mathematics (STEM) fields. Creating instructional and learning materials that can improve meaningful laboratory learning experience for undergraduate students is important. The design and development of such inquiry-based media-rich learning materials can help lay the cognitive and motivational foundations for students to sustain interest and pursuit of future careers in STEM fields (Apedoe & Reeves, 2006; Hofstein & Lunetta, 2004; Nelson, Huysken, & Kilibarda, 2010; Wilson, et al., 2018; Zimmerer, Thiele, Salzer, Krauseneck, & Körndle, 2003).

Open educational resources (OER) provide shared access to the used-to-be costly learning materials and have the attributes for users to retain, reuse, revise, remix, and redistribute freely and openly (Hilton, Wiley, Stein, & Johnson, 2010; Wiley, 2018; Wiley, Bliss, & McEwen, 2014). More relevantly, OER have been demonstrating their effectiveness in improving science learning (Robinson, Fischer, Wiley, & Hilton III, 2014). In addition to the lowered cost, OER science textbooks can offer formats in prints or digital, which means that the possibility of full-color illustration, annotations, animations, and simulations can be used intentionally to

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enhance teaching and learning (Harvey, 2011; Lane & McAndrew, 2010). As digital technologies become more ubiquitous and affordable, OER in digital formats can offer possibilities of innovating pedagogies and learning strategies in blending in-class formal learning with out-of-class informal learning through integration of rich interactive media in STEM education, such as interactive demonstrations, tactile interactivity simulations, and personalized inquiries (Braund & Reiss, 2006).

A review of 20 years of laboratory-based science education and recent results from the Research Experiences for Undergraduates (REU) projects urged the discoveries of effective use and creation of media-based instructional materials using current technologies and meeting the needs of students with diverse abilities and learning styles (Hofstein & Lunetta, 2004; Wilson, et al., 2018). Previous research in developing science media content provided evidences that interdisciplinary collaboration was the key to success (Schmidt-McCormack, Muniz, Keuter, Shaw, & Cole, 2017; Zimmerer, et al., 2003). Designing media-based OER that would meet flexible learning needs required various expertise and skills with content knowledge, learning theories, assessment and evaluation, project and data management, the ability in designing instructions using learning technologies, and the understanding of applying universal design principles for learning. The design and development also anticipated expertise and subject-specific knowledge, an understanding of cognition and learning theories, the capability to use and explore emerging technologies at object and system levels, and the ability to connect related compatibility, manage projects with generated data, and evaluate usability and impact. These would call for new interdisciplinary collaboration and research looking for solutions to complex system issues (Adams, Liyanagunawardena, Rassool, & Williams, 2013; Lane & McAndrew, 2010; Tuomi, 2013). These system issues included instructional design (ID) for content-specific instruction and learning materials, media development, project management, and data management (England & Finney, 2002; McDaniel & Liu, 1996; van Rooij, 2010, 2011; Yang, Moore, & Burton, 1995). With a multi-year project involving members from multiple disciplines, constant formative evaluation became essential to ensure the success of the design and the project as a whole (Nieveen & Folmer, 2013; Popham, 2013; Scriven, 1996; Tessmer, 2013).

Literature Review and DBR Problem Identification

Design-based research (DBR) has the characteristics of "a focus on broadly-based, complex problems critical to higher education; the integration of known and hypothetical design principles with technological affordances to render plausible solutions to these complex problems; rigorous and reflective inquiry to test and refine innovative learning environments as well as to reveal new design principles" (Oliver, Reeves, & Herrington, 2005, p. 103). This current study of developing discipline-specific OER bears these characteristics. To define a complex problem for a DBR starts with a literature analysis (McKenney & Reeves, 2019). In this project, media-supported laboratory learning in science, OER in science education, project management and knowledge management for interdisciplinary ID, and formative evaluation for ID are reviewed for the DBR problem identification.

Media-Supported Laboratory Learning in Science

Science learning has been known to blend concrete experience, active experimentations, reflective observations, and abstract conceptualization, which requires cognitive digestion of theories, concepts, principles, and experiential learning with hands-on activities through experiments in laboratories and field work (Abdulwahed & Nagy, 2009; Healey & Jenkins, 2000; Kennelly, 2009; Kolb, Boyatzis, & Mainemelis, 2001; Shoulders & Myers, 2013). Providing hands-on experience in scientific exploration, laboratory activities have the potential to enhance cognitive growth through procedural and conceptual understanding (Hofstein & Lunetta, 1982). However, the limitation of facilities and teaching resources for science laboratory-based education has not sufficiently fulfilled these learning potential (Hofstein & Lunetta, 2004).

Visuals and multimedia have been consistently identified as effective instructional materials for science education (Clark, Mayer, & Thalheimer, 2003; Mayer, Bove, Bryman, Mars, & Tapangco, 1996). These provide the context for authentic inquiry and appropriate scaffolding in science learning (Bulte, Westbroek, de Jong, & Pilot, 2006). However, effective design and development of media-infused environments are usually built through collaboratively created web-based preparatory resources, which prepare students for real experiments. Zimmerer et al. (2003) conducted a study using Internet-based graphics, videos, 3D representations, and simulations in a data bank co-created by 13 universities. These co-developed web-based media assisted student lab-based learning in an Instrumental Analytical Chemistry laboratory class in Germany. Universities and commercial partners co-developed these electronic media. The virtual access to media-based preparatory materials was perceived by students as increasing learning efficiency with a clarity of explanation and saving time and cost during the real laboratory-based experiments. According to a narrative review conducted by Faulconer and Gruss (2018), nontraditional online and remote labs were increasingly adopted in higher education, and research indicated that well-designed nontraditional labs were perceived as effective as traditional labs in measuring students' content knowledge or attitudinal outcomes.

OER for Science Education

Open educational resources (OER) are defined as "teaching, learning, and research materials in any medium – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation, and redistribution by others with no or limited restrictions" (UNESCO, 2012, p. 1; in Mishra, 2017). OER have been found as systemic changing agents regarding site design, content design, and learning design aspects in a large-scale multilevel study in the OpenLearn project by the UK Open University (Lane & McAndrew, 2010). Tuomi (2013) and Clements et al. (2015) have analyzed and studied the transformational possibilities of OER from individual and distributed perspectives at access, enjoyment, personalization, and experiential levels.

Robinson et al. (2014) studied the effect of OER on secondary science learning outcomes. The study included 4183 students and 43 teachers learning and teaching science classes in 2012 in the fields of chemistry, earth systems, and biology. Due to the fact that random assignment was not possible nor ethical in real teaching and learning scenarios, the researchers used the propensity score matching method to optimally simulate random assignment of samples in using traditional textbooks versus OER. Criterion-referenced test (CRT) scores and the state standardized test scores were used as the dependent variables in the time span between 2009, 2010, 2011, and 2012. Teaching effectiveness was controlled based on the definition of previous OER use experience. The results indicated that the use of OER significantly increased student performance not in earth systems nor biology but in chemistry. Allen and Seaman (2014) conducted a nationwide study about faculty awareness of OER and the use of OER, and the results related to science faculty in higher education were very limited.

Project Management and Knowledge Management in Interdisciplinary ID

The design and development of interactive multimedia involve sophisticated project management procedures (England & Finney, 2002; McDaniel & Liu, 1996; Yang et al., 1995). In an interdisciplinary project, team members bring with each unique social, technical, and motivational attributes. Hoegl and Proserpio (2004) studied 430 team members and team leaders of 145 software development teams. The interpretation of multiple regression analysis results reported suggestions on physical and social proximity, mutual support, and cohesive communication for team-based software development projects. High performance of a team was also perceived in association with critical project leader behaviors and members' sense of belonging, sense of personal success, and perceived team identity. van Rooij (2011) surveyed 103 public and private organizations global-wise that developed educational/training products and found that instructional design projects were closely correlated with designers' project management competencies in practical implementation.

Knowledge management has become integral considerations of instructional design projects as computer-supported collaboration, orientations toward digital object development, and forward-thinking of reusability (Spector, 2002). The role of knowledge management in an ID project was proposed as performance by team members with various subject expertise through the connection supported by librarians (Yang et al., 1995). These included the proper methods of registering digital objects, including but not limited to graphics, audio files, video files, animated objects, and reusable resources. More importantly, the storage and backup of these digital objects would affect the subsequent retrieval, reuse, and standards of different versions in the age of fast evolving digital technologies.

Formative Evaluation for Learner-Centered ID Projects

Formative evaluation, as initiated by Scriven (1996), is meant "to give educators information that could be used to improve still-malleable programs" (Popham, 2013, p. 20). Using formative evaluation iteratively, DBR is anticipated to optimize technology affordances and conducted as socially responsible research to inform ID and other related education practices to enhance teaching and learning (McKenney & Reeves, 2019; Reeves, 2000). In ID practice, small-group surveys, field tests, one-to-one review, and expert reviews can be used as formative evaluation (Tessmer, 2013). Nieveen and Folmer (2013) proposed that formative evaluation for ID project development could be conducted at levels of design principles, design proposal, details of product development, and completed product and could be critiqued from relevancy, consistency, practicality, and effectiveness. Crowther, Keller, and Waddoups (2004) studied the usability of low-fidelity and high-fidelity prototypes of a virtual chemistry class with a case study, as formative evaluation at the development stage and the transition between development and implementation stage. Expert analysis was conducted at the low-fidelity prototype which was at the print stage of the virtual class design. Small-group testing was observed with high-fidelity prototype in actual computer-supported environment. Group reflection feedback was collected as usability test results, which revealed student perceived learning.

Zaharias and Poylymenakou (2009) proposed a framework of e-learning evaluation that included attributes in categories of navigation, support, content, and affective domain. The content considerations included vocabulary, terminology, and presentation of abstracts. The affective domain included "incorporating novel characteristics," "stimulating further inquiry," "being interesting," and providing varied learning activities. The researchers conducted an instrument development study at the initial stage and formulated the questionnaire of 14 items. The questionnaire was distributed to 113 and 260 subjects in 2 pilots, respectively. Results were analyzed to generate interpretations for reliability and validity. The researchers concluded that learners' motivation was associated with e-learning evaluation measurement. Upon acknowledging the limitations of this instrument development study, the researchers also suggest that usability questionnaires would be proper as part of formative evaluation. A heuristic usability evaluation instrument presented by Benson et al. (2002) provided a tool for expert reviewers as well as high-fidelity tests, which included accessibility and learning management system considerations.

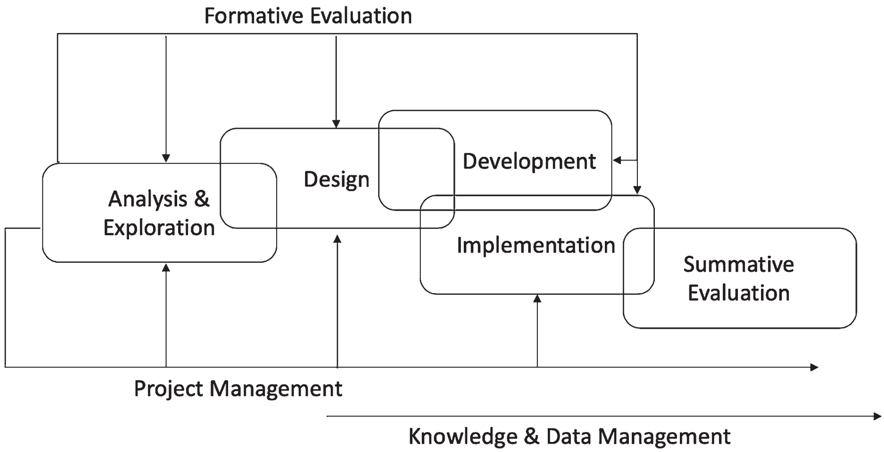

Fig. 1 Formative evaluation, project, and data management for science OER ID

DBR Problem Identification

This current DBR was a multi-year ID project that aimed to create OER for geoscience analytical methods for laboratory classes and was funded by National Science Foundation (NSF). The project team consisted of a geoscientist as subject matter expert, an instructional designer as internal evaluator and lead researcher, a media specialist, and an external evaluator, with support staff from the funded university. For an interdisciplinary ID project, iterative formative evaluation took place at each stage of DBR, including project management and knowledge/data management to determine the effectiveness of project progress and success (Fig. 1). These helped define the research question at this part of the research, that is:

> What are effective procedures for an interdisciplinary team to create low-cost, meaningful, and accessible open access textbooks for laboratory methods in geosciences?

Methods and Context of Research

A DBR strategy was adopted because creating effective and low-cost OER for *Laboratory Methods* Geoscience classes intended to solve a practical and complex educational problem (McKenney & Reeves, 2019; Oliver et al., 2005). This research study was iteratively performed through the following major phases: (1) specifying the research problem; (2) obtaining the necessary information to solve the problem(s); (3) analyzing and interpreting the information that has been gathered; and (4) developing a solution (McKenney & Reeves, 2019). These phases were initially implemented iteratively between August 2016 and May 2019. The research was conducted in the undergraduate-only geosciences department in a comprehensive university on the east coast of the United States and at geoscience conferences. An Institutional Review Board (IRB) protocol was requested and approved at the beginning and subsequently renewed along the project.

Prior to using the newly created OER content, students had to purchase costly textbooks with only static text and images to prepare for the classes. Most geoscience labs were known for their limited space and few instruments. This resulted in limited time for student use of equipment. Instructors' time had to be allocated toward lecturing and demonstration, rather than facilitating student using the equipment to analyze and interpret scientific results. Experimentally, an instructor had to split a class into multiple small groups and teach the complete techniques to each group separately. These required instructors to commit substantial time on planning and coordinating student groups. This needs analysis and a previous study identified that media-based exercises could enhance student learning as informal activities outside formal class time (Liu, St. John, & Courtier, 2017). These activities included viewing online videos, images, and animations, introduction of unit objectives, and reflection with leading inquiry questions prior to classes.

The current project was intended to design and create inquiry-based OER content allowing students to interact with interactive visuals of lab equipment and spend more time for self-reflected learning moments with digital objects visualizing lab environments even without access to the equipment, resulting in cognitive preparation for face-to-face scientific inquiry sessions. The project generated multiple layers of data sources including documentation of design process, developed instructional material, and planned documentation of changes in student learning experience. The process of digital data accumulation inspired intentional exploration of data management of design and development process and files. In the process, the research team adopted a suite of instruments to document the OER development, conduct usability tests, and perform science classroom observations (Benson et al., 2002; Koretsky, Petcovic, & Rowbotham, 2012; Stearns, Morgan, Capraro, & Capraro, 2012).

The design and development of technology-integrated instructional materials for this study involved experts in geoscience, learning science, and instructional design, as well as media arts students and geoscience students. These members from multiple disciplinary areas interacted with content and technologies, collaborated on project management and content presentation, and investigated learning strategies and assessment measures.

Data Collection and Analysis

Throughout the project, the interdisciplinary team constantly used analysis and formative evaluation to appraise the context that could fully use the strengths that each member could bring to the project, to assess technologies that could most efficiently help team communication and create sustainable and accessible content, and to review the project progress to ensure the alignment with the proposed objectives of designing and developing OER (McKenney & Reeves, 2019). The design followed the needs and context analysis to allow a novice student media specialist to operate equipment with optimal confidence and the facility analysis to ensure the compliance with important safety considerations as well as avoid possibility of damaging expensive equipment in a scientific lab environment.

The collected data included communication documents and notification in emails and from Freedcamp (https://freedcamp.com/) and Dropbox (https://dropbox.com) as the initial project and knowledge management platforms. Data also included design documents in Microsoft Word, Google Sheets, diagrams, usability test results, observation notes, and more than 500 images and 200 video footage clips. These covered the content to be developed into OER on scanning electron microscope (SEM), thin-section equipment, Fourier-transform infrared spectrometer (FTIR), and Raman spectrometer. Screenshots were also captured to document the best practices along the process. Text files as outlines, learning activities, and assessment questions were also captured in Microsoft Word, Excel, and Google Sheets. File management and project management was explored through multiple technologies and online services to keep these data sources on the proper track and documentation. Team meeting notes also served as narrative data.

A usability test adapted from Benson et al. (2002) was deployed with an online survey platform that collected qualitative and quantitative data. The same usability test was also used at an expert review prompt through the December 2018 American Geophysical Union (AGU) workshop with participants who were faculty, researchers, or doctoral candidates in geoscience fields (Liu & Johnson, 2018).

Applied thematic analysis was used to iteratively analyze the qualitative and quantitative data to inform the subsequent stages of the project (Guest, MacQueen, & Namey, 2011). The data analysis always took on collaborative interpretation between the subject matter expert and the primary researcher. The initial review and revisit of data to generate themes or interpretation took place both implicitly and explicitly. These analyses served three purposes: (1) finding themes of best practice in terms of best use of student media specialist expertise, optimizing procedures and usage of equipment and settings by constant review and comparison (and sometime updating because of evolving technologies); (2) selecting technologies and methods to maintain or increase the cohesiveness of team productivity; and (3) selecting best procedure to enhance workflow of the project or compatibility between developed digital objects and their interaction with end users.

Results

The results for the ongoing data collection and analysis included those related to shared project and data management, team success strategies, usability tests, and learning-centered design with accessibility considerations.

Project and Data Management

To document the project, the team maintained scheduling and organized record-keeping of project development for multiple individuals across different departments, which required a central virtual space for file sharing and timely communication. Media development needed ample storage space, version tracking, and directory management. The team experimented with and evaluated several tools for low cost, efficiency, and privacy. Platforms tested and used included Google Drive, Google Docs and Sheets, Dropbox, Freedcamp, Dataverse, and Open Science Framework (OSF). After one year of internal formative evaluation, the institutional membership with OSF provided a solution to secured project and data management. OSF kept the version tracking, time stamps, and assigned unique digital object identifier (DOI) for the data and artifacts uploaded to the platform and allowed customized visibility and privacy control of files. The project team developed a customized protocol for the project directory and subfolders with detailed documentation in OSF.

Interdisciplinary Teamwork Strategies

Analyzing team members' strengths and team communication mechanism was one of the keys to the project's successful progress. A student media specialist could bring with her/him unique strengths, such as strong preference of video or image production and not necessarily having the basics of subject-specific scientific knowledge. The team leaders selectively adjusted digital object creation needs based on the student expertise of the year and developed a science research-independent class for the student media specialist so that she/he could learn the basic scientific concepts along the OER development. This independent research class also enabled the physical proximity for team building along with the exemplary behavior of the team leader who learned digital media development along the way. The team also found that allowing a physical regular meeting in the science department allowed the environmental proximity to expedite the project progress.

Leveraging Access, Accessibility, and Shared Cost with Learning-Centered Design

Technologies evolved along this multi-year project and required the team to have a flexible pace based on the constant analysis and evaluation. One year after the project launched, an open-source interactive quiz development software, Zaption Pro, in the initial plan stopped its services. An informal applied research was conducted to evaluate multiple low-cost platforms. As a result, H5P, a new open-access HTML5-based platform, was adopted to develop interactive objects.

Accessibility of images and video was also evaluated along the development. Using the socially shared platform of YouTube was the initial strategy for video publishing. However, the scientific closed captions lacked precision. To ensure the accessibility of these video, text files of proofed transcripts with audio narration were developed to facilitate accurate closed captions. Thirty-six audio clips were separately recorded by the subject matter expert (SME) to apply voice-over to the video (Johnson, Liu, Mao, & Kansal, 2018). For static images, meaningful alt text was created by SME and shared among team members with a Google Sheet that contained the OER digital object labeling so that the team members could follow the development work flow cohesively.

The leverage between the constraints and the needs led to the findings about using shared resources to lower the cost in media content development. After having experimented with a variety of cameras, including those on smartphones of iOS and Android, digital camcorder, and DSLR, the team favored the high-end equipment which was not owned by the team nor the home department. Therefore, a cross-campus collaborative equipment loan was used for media production.

Usability Test and Feedback

The usability feedback was iteratively collected with an online questionnaire adapted from Benson et al. (2002). So were peer reviews from faculty members, researchers, doctoral candidates, and undergraduate students in geoscience fields. Twenty-three undergraduate students and 45 faculty members provided feedback on the computer-based high-fidelity OER, in the contexts of geoscience classes in the university where the project was developed and at the 2018 American Geophysical Union conference. The means of 12 criteria are presented in Fig. 2, including content,

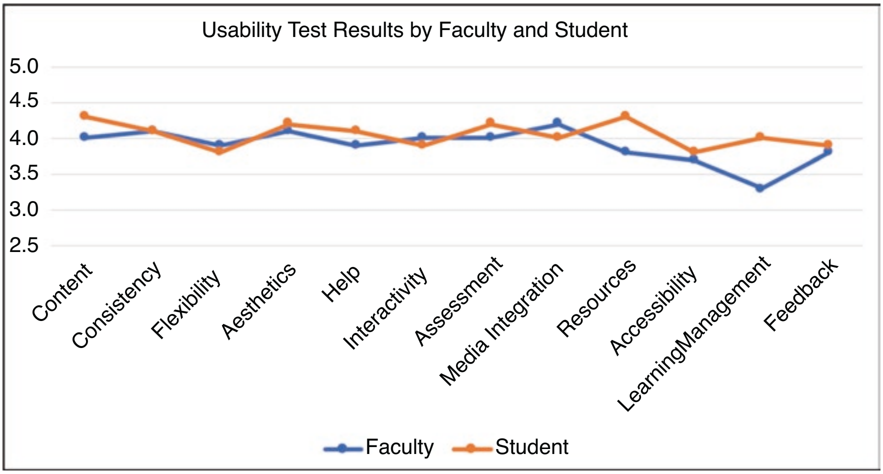

Fig. 2 Usability test results by faculty and students

consistency, flexibility and efficiency of use, aesthetic and minimalist design, help and documentation, interactivity, assessment, media integration, resources, accessibility, learning management, and feedback. Students rated content, aesthetics and simple interface design, help, assessment, resources, and learning management higher than faculty members and geoscientists. Since most geoscience classes had a maximum enrollment of 20 and the usability test was conducted on a voluntary basis with user consent at the end of the class, student participation was limited.

Qualitative data also reflected more in-depth feedback at these high-fidelity usability tests with the pilot developed OER. The content, consistency, navigation and interactivity, assessment, and learning management were positively commented by expert reviewers from geoscience fields, with comments like:

> *The GEO thin section clips are quite clear to understand and show step wise process for each activity. Once they are complete, we will have a curriculum of topics with corresponding videos.*

> while minerology and petrology textbooks are text-heavy paragraphs; it's good this OER is organized by bulleted items which condensed the content

> The content is organized in a way that allows the student to assess his/her own progress clearly.

> The Canvas site is very clearly laid out and easy to use.

> The main page is quite well laid out, and some modules are extremely well laid out.

> I think the guiding questions and check ins were well thought out and useful.

Suggestions received through the formative evaluation were reviewed and adapted on an ongoing basis. These came from the class observations, student media specialist feedback at team meetings, and qualitative comments through the usability tests. At the early stage of a small-group usability test, we received feedback about video length like "I felt the videos mulled over some of the operation of the instruments for too long in some cases"; therefore, the development of video clips was adapted to less than 7 min. The team also started to design and create a centralized references and glossary bank for the OER and evaluate the analytics built in the OER development platform, based on feedback like the following:

> I think many of the pages contain a lot of references and links that although I understand why they would have to be there, it is distracting as a learner.

> It also may be useful to apply some additional features to track progress

Conclusion and Discussion

The OER content generated from this project provides open-access scaffolding for face-to-face laboratory experiences in geoscience courses. Availability and reusability of these materials, especially for costly, delicate, or potentially hazardous instrumentation, may further student interest in the field with maximum access and flexibility. Online informal learning can be designed to support and transfer in-class formal learning through interdisciplinary team-based OER development. The effectiveness of a multi-year OER ID project can be fulfilled with constant internal formative evaluation. These include and result in adapting project needs with team member personal potential, adjusting communication proximity, shared project, and data management and optimizing shared resources on campus to reach efficiency.

The iterative formative evaluation of the instructional design and development provided instrumental information for best practices and guidelines for video, image, and animation production in a scientific lab environment. The usability test results indicated that faculty members or geoscience experts rated the flexibility and efficiency of use, interactivity, and media integration of the developed OER higher than student users. Students rated higher on content, aesthetics of design, resources, and learning management. These could mean faculty had higher expectations of the subject-specific content; students found the learning management system integration valuable as well as using these OER as resources.

The teamwork strategies could be of value to interdisciplinary collaboration on projects and data management for media-rich instructional design projects and for creating accessible media content for science instruction. These reflected the sharing culture of this ID project. Using internal formative evaluation also effectively and holistically organized multiple individuals' work and complicated tasks along the evolving timelines in a multi-year instructional design project.

Not without limitations in such an internal formative evaluation DBR, its findings have suggested the internal formative evaluation go beyond ID process itself. The iterative formative evaluation is needed to analyze team member strengths, team communication mechanism, technology updates, and cross-system interactivity for OER content hosting and publishing. These can also include review and appraisal so that written instructional materials by the content expert are aligned with the formatting capabilities of the publishing platform to link, embed, or add aesthetic features. Feedback from geoscientists has confirmed the needs of human SME interventions along with the use of these OER, such as "better to have an instructor or mentor available to help guide the student and assist with the assessment process." The review feedback has also revealed the possibility of OER integration in various levels of geoscience curriculum.

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Muse Design Studio: Advancing Creative Problem Solving as a Platform for Interdisciplinary Education

Ryan A. Hargrove

It is often the case that design is synonymous with problem solving, innovation, and ingenuity. Design education is built around experiential learning and the pursuit of the unknown (Dewey, 1938; Horowitz & Danilowitz, 2006; Kolb & Kolb 2005; Kolb, 1984, 2015). It would seem logical to start here as a place of beginning when exploring creative problem solving as a foundational component of undergraduate education (Beghetto & Kaufman, 2007; Oxman, 1999; Sternberg & Lubart, 1996; Treffinger, 1995). Much of the framework outlined in this paper is based upon my experience as a design student, instructor, and researcher in the context of studio-based learning. This problem-based method provides an opportunity to engage in an authentic learning experience where students can get immediate feedback on their work from the teacher and their peers. Studio-based learning has traditionally been used in fields like fine arts and architecture. Still, it was not until I began working in a more interdisciplinary setting that a more impactful educational experience began to take shape. As we consider what the future of higher education might or should look like in a world desperate for problem seekers and solvers, I am proposing a way forward through interdisciplinary action. This action is centered around experiences over skills, people over products, and leading over knowing.

For the past decade, I have pursued a research mission heavily invested in undergraduate curricular development at the University of Kentucky. As outlined in Fig. 1, this collective effort has contributed to what is now a pilot program on campus (UK Student Center Design Thinking Challenge) to test and advance innovative teaching methods. The impetus behind this effort has been the aspiration to positively impact the current model of undergraduate education and provide a model for other institutions to follow and improve upon. These experiences began as design-centric courses seeking to develop cognitive awareness and understanding related to

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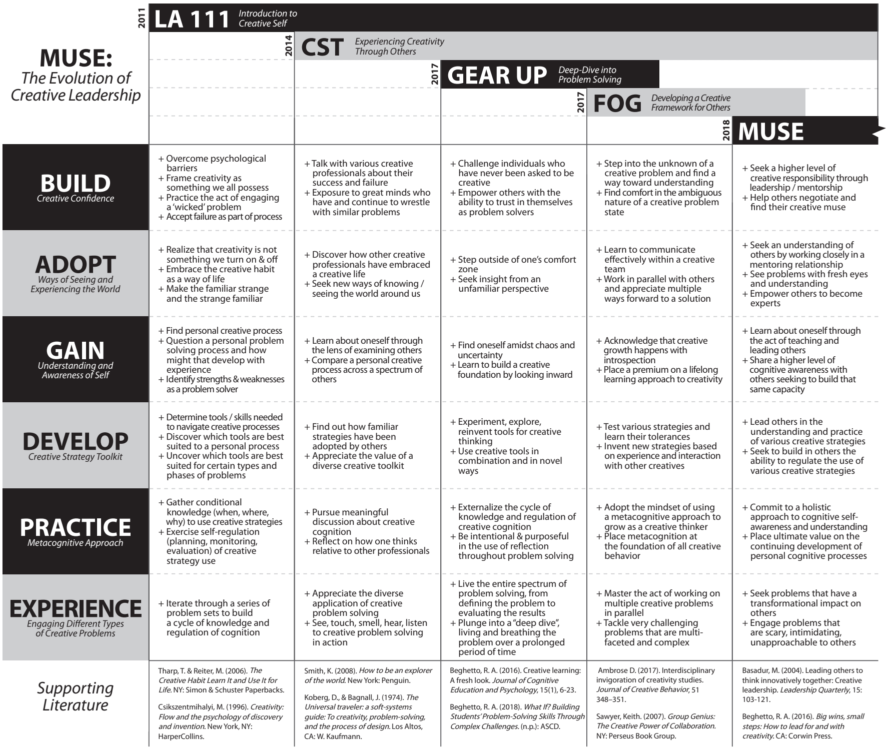


Fig. 1 The advancement of curricular models focusing on creative thinking and creative leadership. (All figures except as noted created by the author unless noted.)

creative problem solving. However, as this effort has continued to evolve, the reach has expanded across disciplinary boundaries. Recent developments continue to maintain an interdisciplinary focus while seeking increased problem complexity through the incorporation of real world problems and stakeholders.

The newly launched program, entitled *Muse*, borrows from previous creativity development experiences (Fig. 2) to forge an immersive experience aimed at elevating students into creative agents of change. Specifically, the goal is fostering creative leadership capacity in which interdisciplinary team members are challenged and guided through a self-reflective experience toward creative mastery. The first year of this ongoing pilot program consisted of a two-semester experience with senior-level landscape architecture students first serving in a leadership capacity in LA 111 (University of Kentucky general education course) during the 2018 fall semester. In LA 111, a cohort of landscape architecture students and faculty engaged undergraduate students in majors across the academic spectrum through the beginning stages of creative inquiry and problem solving. In the 2019 spring semester, a combination of three courses (GEN 109, LA 397, LA 426) was taught communally and transitioned the landscape architecture students into creative leadership roles with

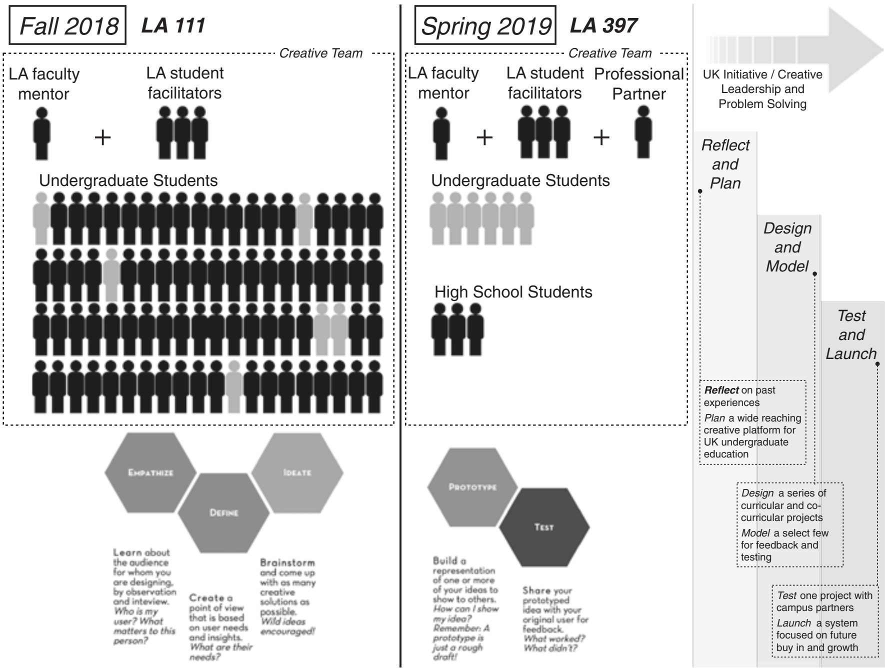


Fig. 2 The relationship between LA 111 and LA 397 during the MUSE program

the courses functioning as a vertical creative studio. The landscape architecture students worked on a project examining ways to reshape the current student tailgate experience on campus with undergraduate students from various disciplines, community and industry partners, and high school students seeking college credit. This team set out to test, prototype, and model potential solutions before proposing a final action plan and helping stakeholders launch the solution into action. Of particular importance is the fact that potential problems were identified and shared through an ongoing Wellness Initiative on the UK campus (Fig. 3). By grounding the problem within the university community, the students immediately became invested and informed through their own personal experiences. This level of expertise is extremely valuable in order to build enthusiasm and a level of foundational understanding. In this model, the landscape architecture students developed skills as leaders in creative problem solving through engagement, teaching, and reflection activities with less experienced students. An ongoing collection of these reflective passages throughout the semester helped students understand and appreciate the impact of this experience as they developed capacity as creative problem solvers and leaders. They were then challenged to develop these ideas, insights, and experiences into real solutions and test each in collaboration with various communities of interest.

The creative challenge identified for this initial exploration was entitled "Fix the Fall, reimagining the student tailgate experience on campus." This challenge was

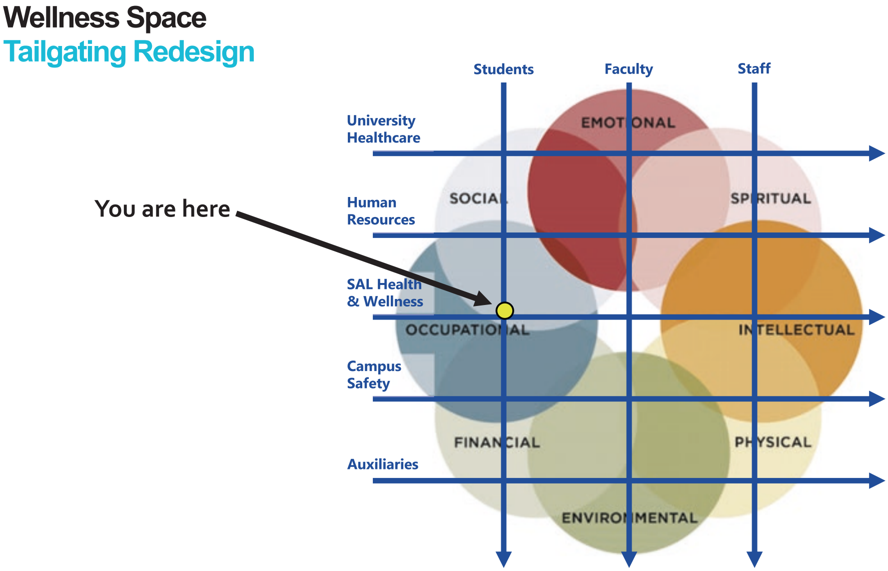


Fig. 3 The Fix the Fall project shown among the spectrum of wellness on UK's campus (University of Kentucky Fix The Fall document prepared by Greg Heileman and Andrew Smith, July 16, 2018)

prioritized by the University of Kentucky President and remains a complex and meaningful issue within the campus community. As with most universities, the student tailgate culture around UK football game days had begun to foster underage drinking and subsequent illegal behavior spilling out of the tailgate experience onto campus and beyond. The student-led group was tasked with utilizing the design thinking approach first initiated in LA 111 to ideate, prototype, and launch a proposed solution. Outside of the product-oriented design deliverables, the team remained equally focused on the documentation of their process and the reflective insight throughout the experience from the perspective of each team member. The documentation of this interdisciplinary exploration was shared on a website designed specifically for the project and can be found at ukla426.com.

The design of the two-semester experience allowed for the transition from a large number of students in the first semester to a small, more immersive experience while maintaining continuity of participants. This continuity created the opportunity for some of the students to embrace the role of creative leadership throughout the entire experience. The beginning stages of the project (empathy, (re)definition, ideation) were able to take advantage of the large number of student participants in LA 111. These 80+ students were able to diversify and capture a robust sample of user input through both interviews and observations. Both helped develop a deeper understanding of the problem and established an empathetic approach from which the problem was navigated. This deeper and broadened perspective facilitated the ability to redefine the original problem into a more informed and descriptive statement. The large interdisciplinary group was also important during the ideation phase to ensure a broad collection of divergent ideas. These ideas would eventually be narrowed through the examination of cases and the identification of convergent themes. During this first semester, the landscape architecture students helped lead this exploration through problem understanding, definition, and imagination. Each one of the three senior students led a section of the LA 111 class, helping shape and discuss the experience for the participating LA 111 students. As the project shifted into the second semester, one of these senior leaders remained and was asked to continue their role as creative leader. The team dynamics shifted during the second semester of the project, from discovering what could be, to communicating a vision for what is to be. A handful of LA 111 students who participated in the first semester continued along with the remaining senior landscape architecture student. This smaller group was also accompanied by a professional partner who specialized in virtual reality modeling. Together the group was able to build upon the work from the first semester while using various graphic technologies to represent and share more site-specific ideas. After multiple feedback loops of prototyping and sharing with various campus user groups, a final design began to emerge. This final design was artfully designed and modeled for a campus administrative audience. Discussions are ongoing as the project continues to move toward implementation.

Key Components of Educational Experience

- ***Multiple semesters*** – this two-semester experience was critical to ensuring students, the creative leader in particular, were exposed to multiple phases and various participants.
- ***Transition of team members***– the dynamic nature of the experience included a transition in team size and representation. This was part of a challenging and formative leadership experience.
- ***Reflection in action***– the entire project was framed as a reflective experience, with the goal of learning from various perspectives and creative approaches to problem solving.
- ***Technology***– in an effort to explore a more effective participatory process, new technology (VR modeling) was utilized throughout the project to share ideas and stimulate iterative feedback.
- ***High level of immersion in problem*** – complex problems require that students live with the problem over an extended period of time. Creative investigation/design is not something that should be turned on and off like a faucet. It is a way of seeing and experiencing the world. Establishing a design studio culture helps ensure that this level of engagement is practiced and appreciated.
- ***Grounded in a current and relevant problem***– finding a problem that is both complex (multifaceted and debatable) and meaningful (level of expertise and interest) for the student participants is critical.
- ***Interdisciplinary***– various perspectives and experiences relative to creativity and problem solving (Fig. 4).

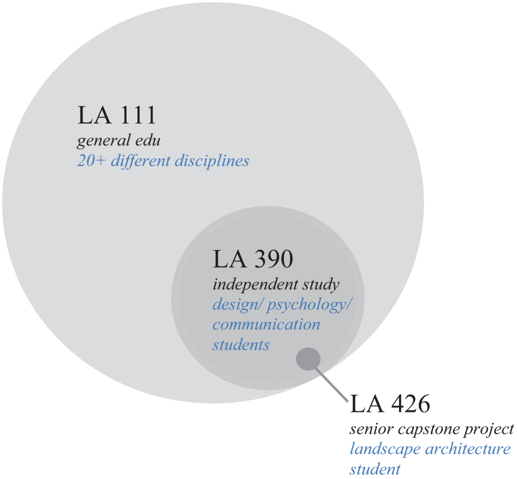


Fig. 4 The relationship of the three courses during the two semester experience

- ***From understanding through implementation*** – while idea generation (divergent thinking) is important, it is only a part of the process. Students need to engage in the challenges/obstacles associated with understanding, framing, sharing, and navigating a solution into reality.

Lessons Learned

The Importance of a Beginner's Mind

Finding a problem that is both multifaceted and complex in nature is critical to the experience. For students it is more important to find complexity in process than clarity in a solution. The value of this experience comes in the moments of uncertainty, doubt, and even chaos. However, these interactions must be intentional, reflective, and informative to how best to navigate current and future problems (Brown, Harris, & Russell, 2010; Casakin & Kreitler, 2011; Gowan, 1972; Wiggins & McTighe, 2005). Perhaps the central role of the instructor in this project was to maintain a dialogue of thought with the team members throughout the project, and when uncertainty arises ensure that this ongoing discussion slows down and becomes a record of shared reflection. This reflection in action is what ultimately builds capacity to grow as a creative problem solver (Schön, 1983, 1987, 1992). In this project we used a custom-designed website to document these discussions along with moments of inquiry and insight.

As with most creative challenges, this particular problem was inclusive of many key factors we had not originally considered. At the outset it appeared very clear how to contextualize this problem. The situation had been documented through outcomes and actions that helped frame the problem as an issue centered around underage drinking. Still, there were numerous issues that surfaced through the empathy and listening stages of our project that were not recognized at the project outset. Looking back, it was essential to begin the project in a position of seeking understanding rather than acting on the initial problem statement. Following a period of broadening perspectives, the project statement was redefined through a deeper understanding and issues such as inclusivity, community, and tradition. Each of these ultimately became driving forces in the proposed solution. From a creative leadership standpoint, one of the strongest realizations by the senior student was the value in finding comfort in that initial stage of ambiguity. He pointed to the power that rests in beginning with an open mind and embracing the fact that you are seeking understanding in a complex space rather than acting to find comfort in certainty:

> *We have dedicated far more time to the initial stages of the project than I anticipated or have practiced in past problem-solving exercises. It took a great deal of patience and trust to rest in these phases on Empathy, Understanding, and Defining. I have learned the value of beginning open, curious, and humble. Ultimately, solving the right problem is most important* (Senior landscape architecture student (creative leadership role). Taken from weekly reflection activities).

In contrast, here is an example of a student participating in the project who did not contextualize the problem and who did not exhibit a strong degree of understanding during this initial phase of the project.

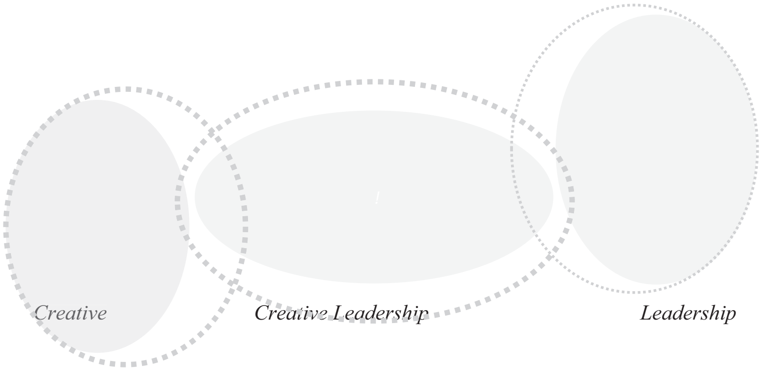
> *I have found the beginning of the semester frustrating. The project is very slow moving as we attempt to learn and understand the context. I see the value in this step but worry about the amount of time we will have to complete the remaining phases of the project. At some point you just need to move forward and begin to solve the issues* (Freshman communications student (creative team member role). Taken from weekly reflection activities).

Beyond Design

Coming from a design background, there is an expectation that any problem will require an iterative process of finding a solution through the association of multiple lines of thought. However, there is a tremendous value placed on finding and representing one best solution in a way that communicates design understanding and intent. In this project there was a concerted effort to make the focus equally about the role of a creative leader in guiding others along a path to clarity. The key aspect was not the product but the experience of dealing with the unknown and helping others who are even less comfortable with the ambiguous state of creative problem solving.

Being a masterful creative problem solver is something that develops over time through endless iterative experiences focused on negotiating complex problems. This characteristic seems increasingly rare throughout undergraduate education in some part due to a reliance on more traditional ways of teaching and learning. By focusing primarily on the goal of acquiring skills and knowledge, students are bypassing the development of cognitive awareness and understanding. Being a proficient leader is also of increasing value and dwindling focus. I would argue that leadership in its full capacity is developed through engagement with problems and people in the context of the unknown and endless possibility. This project placed a priority on utilizing the creative problem state to not only develop an understanding of how to approach and think about complexity but more importantly at a higher level appreciate and embrace the ability to help others reach their creative potential. This project involved students seeking both of these objectives, with less experienced students serving as participants and a senior student assuming a leadership role throughout the project. The interplay and adoption of both learning objectives proved to be extremely enlightening on many levels. Overall, it was made clear that immersion into a complex problem state is unlike any setting in a typical undergraduate experience. By their very nature, uncertainty, iteration, and failure are major roadblocks to most inexperienced students. Figuring out how to avoid and overcome these obstacles provided invaluable lessons that are applicable to any creative problem state. Also, placing the burden of leadership on a student required skills reaching far beyond any one design discipline into more broadly defined areas of human interaction and communication. In that regard it became apparent that creative problem solving is not design; it is at its essence about people and relationships. Consequently, for the senior student, creative leadership became an ongoing quest to relate to and support team members in an ever increasingly complex situation. The ability to do so is more precious than any collection of skills, knowledge, or external artifact. How do we as educators develop and support programs that allow for as many students as possible to encounter this dilemma as many times as possible in preparation for a life of transformative action and influence?

This impetus on creative leadership emerged out of previous experiences leading similar projects where this component was not explicit and purposefully cultivated (Fig. 1). Also, through conversations with professionals who expressed frustration with high achieving graduates entering the profession as being technically and creatively proficient but lacking the ability to step into a creative leadership role. Some of this is no doubt fostered in the professional setting, but in most cases entry-level graduates are being asked to produce work with few opportunities to grow in this capacity. Employers are finding 3–5 years later that these highly skilled employees are not prepared to step into *creative leadership*. Also, it is becoming apparent that hiring someone with the mindset and potential to be a difference maker involves them not only having creative skills but the ability to advance another's creative capacity. Ironically this in turn advances their own capacity to problem solve. In my experience, creative leadership cannot be defined as possessing attributes of both creativity and leadership. I think this rare but valuable skill set is distinctive and should be developed as such throughout a student's education (Fig. 5).



- Novel
- Capacity to elevate another's creative approach
- Good communicator
- Imaginative
- Build metacognitive awareness in others
- Commitment and passion
- Divergent thinking
- Willingness to prioritize advancement of others
- Inspire others
- Open minded
- Foster creative behavior and mindsets in others
- Strategic thinker
- Associative thinking

Fig. 5 The distinctive qualities of creative leadership in relation to creativity and leadership

Technology Bump

One of the new explorations in this project was the use of virtual reality to model potential solutions. The use of this technology allowed each of the proposed ideas to be shared across a group of users prior to finalizing a solution. The virtual platform was extremely helpful in accurately representing potential solutions in a way users could richly experience and respond. The virtual model allowed users to be placed into a proposed physical space, engaging multiple senses through interaction. For many of the students, this technology was initially viewed as a powerful way to share their ideas. Still, the ultimate power of VR as tool was far beyond its advanced capacity for graphic representation. Utilizing VR allowed the team to engage the user in a way that generated meaningful feedback. A key to this from a user perspective was both an excitement and willingness to use the technology and a sensory-rich experience that prompted thoughtful and multifaceted responses.

Nonetheless, there should be caution in allowing the use of VR to become a focus of the exploration (product) rather than a tool in generating discussion (process). In this project many of the users were enamored of the technology and some familiarity was needed before the conversation could move into more meaningful feedback. The interaction with users experiencing the VR model must be intentional and focused in order to avoid distracted or technology-centric responses. Undoubtedly, VR is a new pathway for insight but should be monitored to ensure the power is realized in a way that allows for greater understanding and in-depth dialogue of ideas.

Next Steps

The Muse model has provided an interdisciplinary framework for the undergraduate landscape architecture students as they acquired expertise in creative leadership through a collective deep dive into a complex problem. It is the experience of working in a leadership capacity and negotiating the problem while helping others find their creative muse that prepares these students to have the largest impact as agents of change. The impact of the lone creative genius is insignificant compared to the capacity to develop in others the ability to see and experience the world through a creative lens. As the initial pilot period concludes, the Muse program will be evaluated and modified before seeking a permanent place within a collection of newly launched creative initiatives on campus. The ultimate goal is for the Muse program to empower students and educators across campus and beyond to seek opportunities for creative influence, and in doing so build a network of experiences aimed at illuminating complex problems and elevating students with the capacity for transformative change.

Moving forward, the Muse program will be constantly evolving as the scope of the projects includes challenges that are both current and meaningful across communities of scale from campus, the city of Lexington, and the state of Kentucky. In doing so, this program will expand into serving as a laboratory for creative pedagogy, problem solving, and community/campus outreach. Following the 2019 spring semester, I will be dedicating time for reflection and refinement before launching an effort in the 2019 fall semester to design and implement a new series of pedagogical innovations related to creative leadership and problem solving. This initiative will address the development of new experiences throughout the undergraduate experience. The objective is to model a variety of pathways so every undergraduate student at the University of Kentucky will have an opportunity to infuse creative problem solving into their curricular and co-curricular activities. This model will require rethinking how undergraduate education at the University of Kentucky is currently advancing student growth related to interdisciplinary experiences, collaborative learning, and creative problem solving – all of which are central to the ever-changing demands of the workplace. The outcomes of the project will facilitate university buy-in, model a series of meaningful changes, and help establish a permanent center that will focus on bringing these projects into action while exploring future directions. Beginning in the 2019 fall semester and continuing over a 3-year period, I plan to incorporate what I have learned through my past efforts and ongoing pedagogical practices, model a series of new initiatives, and solidify a presence on campus moving forward.

The Power of Permanence

The Muse program is influenced by a model entitled *Into the Fog* I first explored in partnership with Vanderbilt University during the 2017 academic school year. That project looked closely at the undergraduate experience at Vanderbilt and how a series of curricular, programmatic, and environmental enhancements might nurture long-term, transformational change across campus. With the help of this project, Vanderbilt has launched a new campus initiative called DIVE with the goal of requiring an immersive creative experience for every student before graduation (https://www.vanderbilt.edu/immersion/dive/). The following website was created as a part of the project to help document and share the findings: https://waho223.wixsite.com/intothefog.

The programs at Vanderbilt helped reinforce a belief in the power of place. Despite its shortcomings, the physical infrastructure and programming made possible through a permanent facility were striking. As part of the upcoming reflection period, I will think carefully about how a similar space at the UK would work given its unique outreach mission as a land grant institution. In addition, the timely nature of UK's developing "innovation district" provides a tremendous opportunity for a permanent home as a part of a larger campus initiative. As shown in Fig. 6, this program would carefully consider how to develop a three-part mission of outreach, education, and research, with an approach that allows each to inform and strengthen one another. Of particular importance is how each of these areas would function specific to programming and spatial synergies.

Moving horizontally across the graphic in Fig. 6, the interaction of *mission* (outreach, education, and research), *program* (Into the Fog, Muse, Meta Lab), and *space* (public, studio, laboratory) become evident. Viewed holistically as a system, it is important to recognize the significance of ongoing interaction and growth. Reading vertically the pillars of outreach, education, and research are framed along with suggested programmatic and spatial organization. Again, these are not to be viewed in silos and were developed to overlap and interact accordingly.

At its core the project and place are grounded in a desire to advance undergraduate education. In terms of output, there are certainly desired outcomes related to outreach (impact on community) and research (impact on a body of knowledge). However, central to this project is a strong desire to strengthen undergraduate education through a focus on creative leadership, applied learning, problem solving, and visual communication. Therefore, education and the Muse design studio component remains central, as the outreach and research components support and inform (Fig. 7).

MISSION	**Outreach**	**Education**	**Research**
	• Engagement at various scales of community from campus (UK Wellness Initiative), city of Lexington (town /gown relationship), and state of Kentucky (various complex challenges). • Effort in support of land grant mission of University of Kentucky and in response to communities of need across the various scales. • Problems would fall along a continuum of complexity and would be selected on criteria comprised of all three elements of mission (outreach, education, research).	• In coordination with Chellgren Professorship design a permanent program based on the development and utilization of creative problems solving, visualization and leadership. • Potential to connect with Kentucky high school students (see Gear Up model) as well as high achieving students at UK already participating in Gaines, Honors, Chellgren, etc. • As a permanent program/major/degree there is potential to engage various levels of education from undergraduates (UK Core) through Post Doc students.	• Threads of research centered around pedagogy and future models of teaching and learning. • Potential for corporate and industry partners - collaboration, internships, funding on projects. • Grant funding for long term projects and research initiatives (see UK opioid study) • Find ways for Education and Research to inform one another. Study the teaching and learning taking place in the Muse studio. Modify approach to teaching based on Meta Lab research findings.
PROGRAM	**Into the Fog**	**Muse**	**Meta Lab**
	• Interdisciplinary teams comprised of UK students, faculty and community members. • Participatory model seeking partnership with various UK entities - CAFE (Community, Leadership and Development / CEDIK), UK Healthcare. • Fold in expertise from the campus community based on the nature of a particular problem. • Sharing of work in open workshops, galleries, and online models.	• A continuation of the pilot project with the goal advancing a curriculum based on multiple experiences negotiating complex problems. • At its core this program is built around the tenants of creative leadership, applied learning, problem solving and communication (focus on visualization). • A model for how best to foster creative thinking in the K-12 setting. Developing a partnership with the College of Education is critical.	• Commitment to offering creative engagement and exploration to UK community of students and faculty. • Potential tie into College of Education graduate and PhD student research. • Seek K-12 partners in Kentucky schools for applied research in the classroom. • Find and attract students with goal of creative leadership and/or community outreach.
SPACE	**Public**	**Studio**	**Laboratory**
	• Flexible space that opens to the public / streetscape • Gallery and wall space dedicated to sharing both process and products • Accessible to guests and visually engaging with pedestrians, vehicular traffic	• Core space for permanent instructors, students, staff. • Based on a design studio culture - 24/7 access, immersive experience into various problems with a team of students, faculty, partners.	• Shared work space for interdisciplinary research teams • Project work space for pin up / presentation of work • Proximity or overlap of use with Muse studio space for sharing of information and ideas.

Fig. 6 Envisioning how an innovation space would align with the pillars of a land grant institution

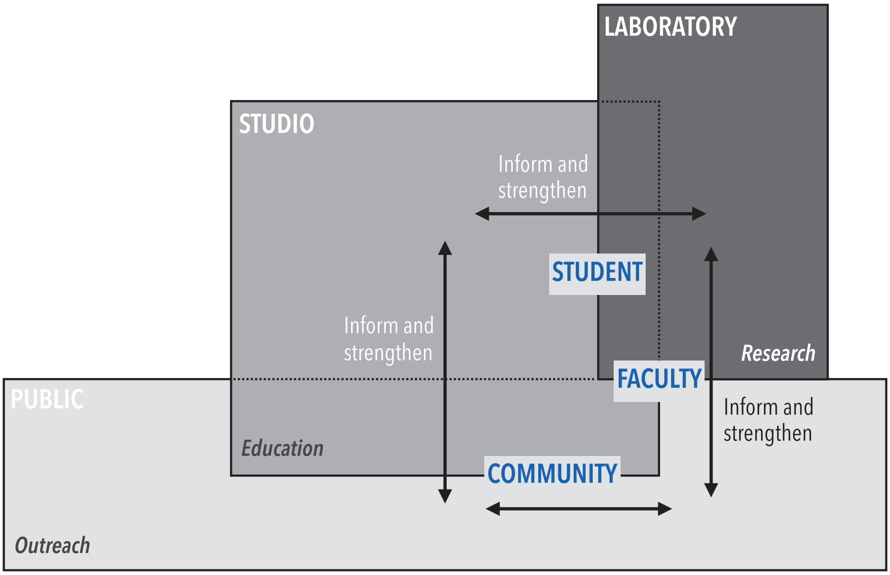


Fig. 7 Visualizing the interplay of physical space, desired outcomes and participating parties

Ultimately, the ongoing development of Muse has enriched and solidified my belief in an interdisciplinary approach for creative problem solving – an approach grounded in a process-driven curriculum, reflective practice, innovative documentation and dissemination of information, and a diverse and multifaceted strategy for reaching a wide portion of the undergraduate population. Looking forward, the University of Kentucky has a tremendous opportunity to develop not only the physical infrastructure to support an innovation district but more importantly the relevant programming needed to allow this infrastructure to optimally serve and impact students.

Conclusions

From an educational standpoint, the curricular approach highlighted in the Muse project is challenging to implement due to the intensity required for an immersive experience. As mentioned previously, there is tremendous value associated with deep immersion into a complex problem. Living with a problem over a significant period of time and having the ability to be flexible and fluid as the problem changes over time is not easily accommodated in the current disciplinary structure of higher education. It is difficult to quantify the value added by spending an extended period of time with the problem and focusing on creative awareness and self-reflection. Educators must find prolonged exposure with a problem in order to provide opportunity for rumination, reflection, and adequate focus on developing a personal creative process (Cross, 2006; Isaksen & Treffinger, 2004).

Also, of note is the fact that there are a very small number of creative leadership opportunities across campus. As outlined, this skill is distinctive and not the result of mastering creativity and leadership. I think this in part makes it difficult to measure and justify as a learning outcome. It also requires a large investment in time for what in the Muse example resulted in one student having an in-depth experience. It is tough to imagine this being sustainable unless this process is phased through levels of participation across a student's academic journey. This in turn leads to the question of scaling this experience out and making it accessible to more students. Certainly aspects of this experience could be brought into other courses and perhaps even co-curricular opportunities. However, I think the answer is most likely to be found in breaking away from strict degree programming and encouraging students to grow in ways that transcend disciplinary boundaries.

Finally, there is the question of finding the right balance of ideas and implementation. Depending on what students study on campus, there can be a strong emphasis on one or even both ends of this spectrum. Ultimately, I think the key is appreciating the fact that by their very nature creative problems are uncommonly prickly and unpredictable. Therefore, it is essential to be proficient in not only thinking beyond what is commonly assumed possible but also finding ways to make these novel ideas achievable in a world accustomed to habit and procedure. How can educators best prepare future difference makers to live in this space that shifts from divergent to convergent thinking constantly as the very nature of the problem evolves around them? The Muse experience and a decade of other studios before it would support a model of authentic practice, facing a multitude of challenges throughout the entire creative process: many of these challenges as a creative participant and several others assuming the role of creative leadership.

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Interdisciplinarity and International Education: Creating Opportunities for Collaboration in Design Research and Practice

Genell Wells Ebbini

Introduction

There is a transition underway in higher education that challenges our current approaches to research, teaching, learning, and practice. An awareness of the effects of globalization has led to increasing interest in collaborations that are both international and interdisciplinary in scope (Altbach, 2013; Charles, 2015; Deardoff, de Wit, & Heyl, 2012; International Association of Universities, 2012). The need to develop a global perspective on our work as scholars and practitioners is becoming an urgent discussion in many fields. These broader understandings of intellectual endeavor are particularly relevant to the ways in which we train the thinkers and problem-solvers of tomorrow, which is to say, our students.

The significance of globalization for higher education and the unique cultural and conceptual challenges that it poses have been discussed in great detail by scholars such as Asha Mukherjee (2016) and Thomas Friedman (2000, 2005). Many important issues arise in these conversations, including the prospects of diversity in a world that is increasingly "flattened" by global interactions, the rampant growth of inequality that is part of globalization's legacy, and the best ways to address ecological and social challenges that are increasingly international in scope.

Of course, fully solving such problems is far beyond the scope of the current paper. What I would like to discuss, however, is how we as educators can best prepare our students to meet these challenges and to operate effectively in their future careers in an increasingly globalized professional environment. In design fields, *globaldesign thinking* is becoming a prevalent aspect of professional practice and employer/client expectations. Designers who are global thinkers are socially and culturally respon-

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sive, aware of international issues, and competent at respectfully communicating with individuals from truly diverse backgrounds (Crawford & Kirby, 2008; Kimbell, 2011; Salmon, Gangotena, & Melliou, 2018). Educators should recognize this industry need and should take steps to provide students with the essential tools and pedagogical experiences that will allow them to thrive and contribute in a globalized world.

The Need for Interdisciplinary and International Experience

Scholars who specialize in educational research have shown that courses offering immersive international experiences can have a tremendous impact on the development of students' worldviews, values, and cultural engagement skills. Such opportunities are most effective when they expose students to global issues and to the needs of a diverse or unfamiliar population (Byrnes, 1997; Charles, 2015; De Blij, 2005; Tye & Tye, 1992). Study-abroad programs provide students with an opportunity to develop intercultural competency, self-esteem, confidence, openness to new experiences, and positive attitudes toward cultural differences, all of which are important professional development goals in today's employment marketplace (Bennett, 1986, 2013; Engle & Engle, 2004; Henthorne, Miller, & Hudson, 2001; King, Perez, & Shim, 2013; Maharaja, 2018; Mills, 2010; Omachinski, 2013).

Psychologists have analyzed and quantified the effects of international study experiences in relation to personality development. Studies have found that both short-term and long-term trips can be effective pathways to lasting gains in sociability, creativity, openness to experience, and emotional stability (Cheng & Yang, 2019; Markman, 2013; Ritz, 2011; Zimmerman & Neyer, 2013). While conventional academic wisdom sometimes dictates that short international tours are too superficial to yield meaningful results, research on this topic has shown that even a brief "sojourn abroad" can provide significant enhancements in social and intercultural skills, as well as great leaps in knowledge-development, if the program is effectively designed (Omachinski, 2013, pp. 46–47). These programs can increase students' ability to recognize both shared values and legitimate cultural differences, prompting more thoughtful and nuanced outlooks on global relations and development challenges (Bronfenbrenner, 1979; Deardorff, 2006; Doerr, 2013; Schwartz, 1992).

Institutions of higher education are increasingly encouraging faculty members to develop short-term study-abroad programs to help more students achieve a measure of these cultural skills and to enhance global citizenship grounded in a personal awareness of international social issues and human rights (Mills, 2010; Mule, Audley, & Aloisio, 2018; Salmon et al., 2018). The most important task for educators who want to develop such study-abroad courses is to become familiar with the practical means of achieving these educational goals in a safe and effective fashion.

This paper describes a short-term, faculty-led international study tour that the author created and implemented. The course provided advanced undergraduate and graduate students in design fields at a major US university with an immersive cultural experience in Jordan. The general course development was based on a review of grounded theoretical frameworks related to intercultural competency, most notably the Bennett scale (also known as the Development Model of Intercultural Sensitivity, or DMIS; see Fig. 1) (Bennett, 1986, 1993, 2013; Bennett & Bennett,

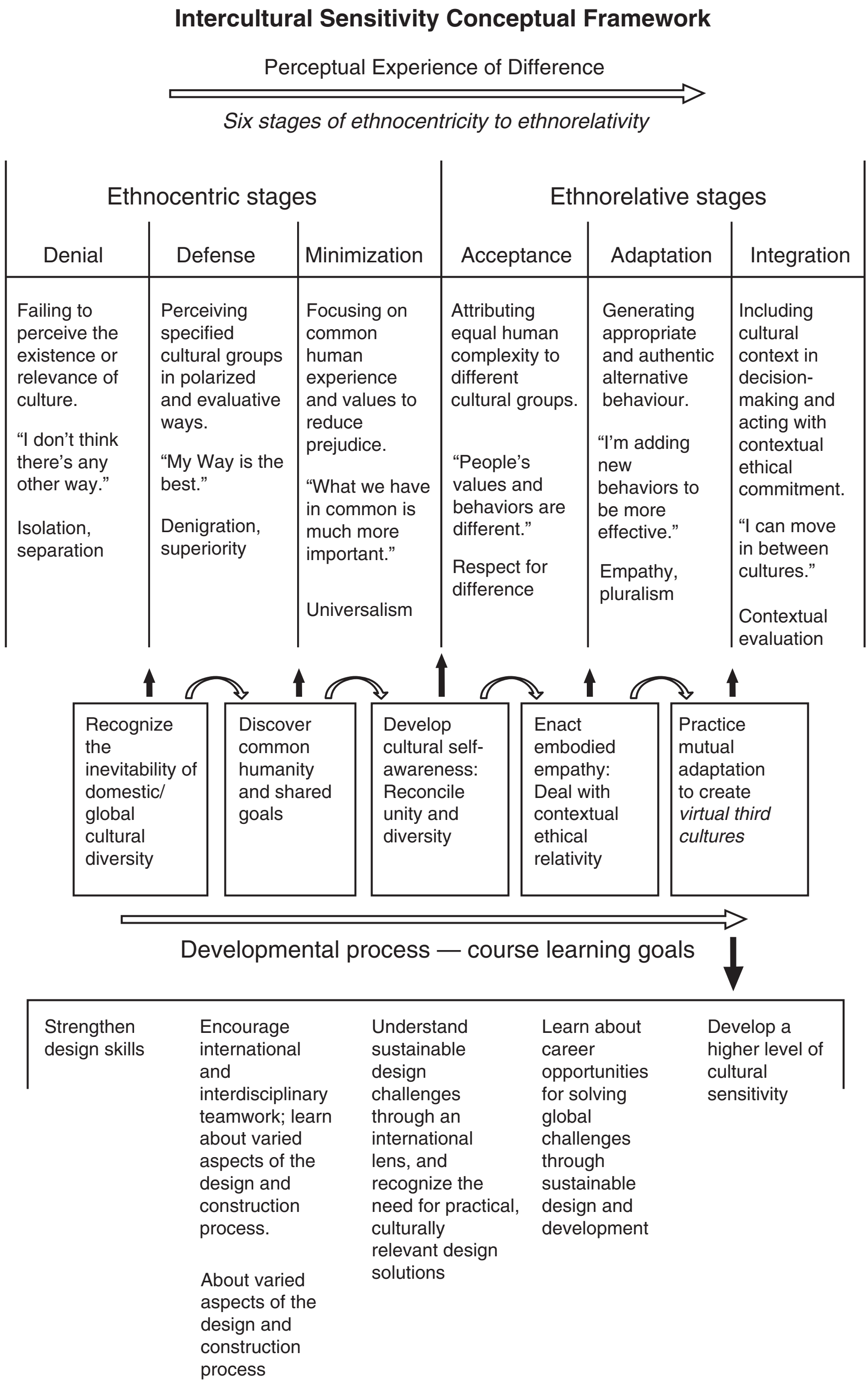

Fig. 1 Conceptual framework aligned with course goals. (Adapted from Bennett's Developmental Model of Intercultural Sensitivity (DMIS) used to rate the degree of ethnorelativity from low (ethnocentricity, the individual display ethnocentric behaviors—one's own culture is central) to high (ethnorelativity, the individual display full integration to another culture—one's own culture is seen in the context of others) (Bennett, n.d., 1993, 2011))

2004; Bennett & Castiglioni, 2004). The Bennett scale also served as one of the measurement frameworks for assessing the program's success and the resulting student outcomes. The DMIS framework uses the concepts from constructivist psychology and communication theory to assess students' intercultural sensitivity—primarily assessing how students experience and engage in cultural differences (Bennett, 2017).

The specific course curriculum was based on sustainability goal-driven approach using the "Integrated Design Process" (IDP) in which each student focuses on the design, construction, and long-term operation of a single building throughout its complete life cycle (Table 1). Students' evaluated the elements of the IDP process to assess the high-performance buildings that contributed to sustainable development in Jordan. The IDP process assisted students in understanding the challenges of collaborative international design processes that focus on the design, construction, operation, and occupancy of a building through the lens of intercultural sensitivity. Analyzing the historical trajectory of the decision-making processes in this fashion can help students to better grasp long-term cultural, economic, and environmental concerns relevant to design (Stipo, 2015). Doing so in an international and interdisciplinary context has the effect of broadening design students' horizons, encouraging them to think about crucial practical issues in international design and sustainable development that their own backgrounds may not have prepared them to consider. Meanwhile, it provides crucial opportunities for the students to interact directly with local design practitioners and building users, enabling them to understand cultural diversity in a direct and immediate fashion and to develop their skills in multicultural dialogue and information exchange. Strategies and methods that demonstrate cultural sensitivity are not a standard IDP approach in the design and development of sustainable high-performing buildings.

Table 1 Elements of integrated design process (IDP) (derived from Kyvelou & Floros, 2013)

Elements of integrated design process (derived from Kyvelou & Floros, 2013)
Emphasize the *integrated process*
Thinking of the building as a *whole*
Focus on *life cycle design*
Work together as a *team* from the beginning
Conduct *assessments* to help identify requirements & set goals
Develop *tailored solutions* that yield multiple benefits while meeting requirements & goals
Evaluate solutions
Ensure *requirements and goals are met*

Note: IDP is an iterative process, not a linear or silo-based approach. It is a flexible method, not a formula; different each time, not predetermined; and an iterative process with ongoing learning and emergent features, not a preordained sequence of events (Busby et al., 2007, p. 5)

Instructional Framework

The course was organized by the author in coordination with my home university's study-abroad office and our international partner institutions. The number of participating students was kept limited (fewer than ten, with a total of seven students ultimately participating on the trip), in order to ensure that one faculty member could provide adequate supervision and mentoring for the students' in-depth cultural experiences. The participants included a mixture of upper-level undergraduates and graduate students in design fields. After extensive preparation, the students spent a total of 16 days in Jordan. The goals of this short-term study-abroad immersion were explicitly enumerated to the students as follows:

- Strengthen design skills.
- Encourage international and interdisciplinary teamwork; learn about varied aspects of the design and construction process.
- Understand sustainable design challenges through an international lens and recognize the need for practical, culturally relevant design solutions.
- Learn about career opportunities for solving global challenges through sustainable design and development.
- Develop a higher level of cultural sensitivity.

In creating the course, the author followed a distinct and organized process from the initial concept to the final student assessment, requiring approximately 2 years in total (Table 2). First, the learning goals and pedagogical approaches of the course were defined, and then specific techniques and itineraries for achieving those goals were developed.

Pedagogy and Goals The Bennett scale presents a framework to describe how individuals experience and engage with cultural differences—ranging from the perception that one's own culture is the immutable center of reality (ethnocentrism) to the perception that human behavior is entirely relative to cultural contexts (ethnorelativism) (Bennett, 1986, 2013; Hernandez & Kose, 2012). While extreme forms of ethnorelativism are ethically and conceptually incoherent, most humans tend toward the ethnocentrism side of this scale and can benefit from developing greater fluency, tolerance, and understanding in relation to cultural differences. Based on the Bennett model, the course was designed to offer students an opportunity to progress through the stages of ethnocentricity to ethnorelativity (Bennett, 2013, 2017) (see Fig. 1). The ultimate goal of this process is to reach an improved understanding of culture (both one's own and others') and to prompt personal growth and advanced critical thinking about cultural practices and values through reflective practices (Howlett, Ferreira, & Blomfield, 2016).

In addition to developing stronger intercultural skills, the course was designed to introduce students to the Integrated Design Process. Traditionally, IDP has been

Table 2 Process in developing the collaborative approaches toward sustainable development short-term study-abroad course

Step 1
Planning
Written Proposal
Approval
IRB Submission
Investigation/Coordination
Study Abroad Faculty Agreement & Training
Step 2
Promotion/Marketing
Information Sessions
Address Institution Safety Concerns
Students Commitment
Commitment/Deposit with Travel Agency
Step 3
Conducting
Pre-Departure Documentations (passports, insurance, etc.)
Pre-Departure Meetings with Students – Conduct Agreements
Arrival – Site Tours
Post-Experience
Step 4
Reflective Evaluation
Students
Faculty
Institution
Step 5
Dissemination
Media
Conference Presentations/Papers
Peer Journal Article

Adapted from Eckert, Luqmani, Newell, Quraeshi, & Wagner, 2013

regarded as a type of design practice, intended to help professionals take account of the full building life cycle and the long-term effects of design decisions (Larsson, 2009). The use of this approach is strongly linked to sustainable design and to the integration of diverse interdisciplinary perspectives. Designers using IDP are likely to seek out input from their colleagues in other design and construction fields, as well as from facility managers and even from sociologists or building users themselves, to better understand the ways in which design can meet human needs and effectively support environmental and social goals (Busby Perkins+Will & Stantec Consulting, 2007; Larsson, 2009; Stipo, 2015).

IDP can also be used in an educational context as a way to encourage students to think more broadly about sustainability issues and to develop skills in interdisciplinary communication. For the current project, the author used IDP as a framework to promote interdisciplinary education *as well as* international collaboration and cultural exchange. IDP is well-suited for this purpose, since it already includes an emphasis on learning about the needs of building users and the practical, life cycle concerns of building construction and operation. This type of systemic, long-term thinking about design integrates well with the goal of promoting cultural awareness and immersive international encounters. It encourages students to think about contextualized human needs and design considerations that they may have otherwise tended to overlook.

The author integrated IDP into an systematic structure of learning so that each student could analyze the life cycle of a "green" building in Jordan, thereby gaining technical knowledge of sustainable development challenges in a non-Western context, as well as targeted intercultural competencies in interacting with a non-Western design team (Deardorff, 2006; Deardoff et al., 2012; Odag, Wallin, & Kedzior, 2015). Jordan is one of the first countries in the Middle East to take positive steps toward implementing a robust sustainable construction agenda, which makes it an ideal context to pursue this type of immersive educational opportunity. Amman, the capital city of Jordan, is one of the Rockefeller Foundation's "100 Resilient Cities" and has created a comprehensive strategy to promote social and environmental sustainability (http://www.100resilientcities.org/strategies/amman/). Jordan offers students an incredible place to study abroad due to its historical, political, and cultural significance in the Arab region. The security situation in Jordan also makes it one of the safest Middle Eastern countries for Western students to visit—in Gallup's Global Law and Order Report, Jordan was ranked as the ninth safest country in the world, just behind Finland (8th), while the United States was ranked 26th (Gallup, 2017).

Course Design and Preparation After establishing the pedagogical goals and general outlines of the study tour, the author/instructor contacted international organizations, private companies, and government representatives to support the planned educational activities. These partners included the Jordan Green Building Council; Habitat for Humanity, Jordan; the Jordanian Royal Academy for Nature Conservation; several private architecture and design firms; and a few senior officials in the planning department of the Greater Amman municipal government. The author's prior experience of working professionally in Jordan helped tremendously in identifying these contacts and securing their participation. The course planners conducted virtual meetings with representatives from partner institutions in the months leading up to the tour and sketched out an itinerary based on their availability to meet with the students. The planners also used a travel agency to assist in making reservations for accommodations, meals, and other trip logistics.

Meanwhile, participating students carried out extensive pre-departure work, including researching and watching videos about Jordanian geography, languages, cultures, and customs. The students were required to review documentation about all of the buildings that they would encounter during the tour and to learn about

Jordan's overall sustainability initiatives, public health concerns, and social issues (in particular, Jordan struggles with significant water-use concerns, and the country is currently hosting an enormous number of refugees from the nearby Syrian conflict).

Prior to the trip, each student was assigned to prepare a preliminary IDP analysis of a building in Jordan that had been certified as "sustainable/green" by the Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system. In addition to reviewing conventional sustainability metrics such as energy efficiency, the students analyzed the ways in which the buildings are intended to meet human needs and how they encourage conservation behaviors and "green outlooks." The students then examined the social, political, and economic challenges relevant to each design project and the strategies that were used to overcome these challenges. Finally, the students also met socially with international peers and faculty members from the region, as a means to learn more about Jordanian perspectives and to create excitement and enthusiasm for the tour.

Trip Activities

During their first week in Jordan, the students traveled throughout the country to experience its culture and heritage and to *see* the environmental conditions—a kind of personal immersion that is vital for designers to successfully approach the context of their creative work. During the rest of their time in the country, they stayed in the capital city of Amman, where they met with representatives from partner institutions and carried out studies of the selected buildings.

The initial travel period was focused on field excursions to notable cultural sites and ecological locations, as well as interactions with ordinary Jordanian citizens in informal contexts. To prepare the students to participate in conversations about the design and development of sustainable practices in the country, the course planners felt that it was essential that they not only *read* about the environmental and cultural context but also gain firsthand immersive experiences, particularly in the country's rural areas. The students learned about the different regions throughout Jordan and the specific social and environmental challenges in each region. During this time they also had the opportunity to meet with local nature conservation organizations and discuss the concerns of these groups.

Sites that the students visited during this period included the Dana Nature Biosphere Reserve (which encompasses four different biogeographical zones), the Ajilun Natural Forest (where students met with representatives of the Royal Academy for Nature Conservation), and the Dead Sea (where students learned about the role of the Royal Society for the Conservation of Nature). The students also spent one full night and day exploring the Wadi Rum desert with a Bedouin teacher, who described how he and his ancestors "read" the land to survive and flourish. This allowed the students to gain a better appreciation of the close interconnections between the ecological and cultural environments of Jordan. The students also visited several UNESCO World Heritage sites, including parts of the Silk Road, the ancient rock-cut architecture at Petra, and other significant architectural landmarks. While in the city of Petra, they participated in food preparation and shared an authentic local Arabic meal, family style, with a Jordanian host, thereby experiencing the significance of hospitality in Jordanian traditions.

After returning to Amman for the second phase of the trip, the students engaged in collaborative learning activities that connected them with government representatives, professional associations, design firms, and prominent community leaders. In addition to offering professional networking opportunities, these activities allowed the students to see how various design philosophies, ethics, and cultural values interact during the process of addressing global environmental and social challenges. The goal was to instill in the students a sense of empathy, social consciousness, and awareness of diversity, so that they could work more effectively across international and intercultural boundaries (Dong, 2004; Durrer & Miles, 2009). The Jordan Green Building Council (JordanGBC) organized an orientation day in Amman, during which students met with the JordanGBC Board of Directors and participated in lectures on topics ranging from energy efficiency initiatives to affordable green housing.

The majority of the students' time in Amman was spent visiting the contemporary building sites that they were studying and engaging with local interdisciplinary design teams and governing agencies. They discussed with these teams the predominant sustainability concerns that they were facing—most notably the rise of forced migration and the influx of refugees and the resulting crises in resource use and housing affordability in Jordan. The students learned about how professionals in the design and construction industry, with the support of the Jordanian government and international donors, were working to address this crisis and promote sustainable development. They discussed the concepts of bioregional planning and the intersections of sustainability, local culture, and social equity, while meeting with developers, industry representatives, and senior municipal officials. The course adopted a constructivism approach to learning by providing students "hands-on" learning opportunities to solve "real-world" problems as students "dive deeper" into the complexity of sustainability issues in the region (Hedden, Worthy, Akins, Slinger-Friedman, & Paul, 2017, p. 17). All of these activities helped to assist students in the preparation of their primary course assignments—an evaluation of the effectiveness of implemented sustainable design strategies in meeting the social and ecological needs of Jordan (Fig. 2).

In addition to the site visits and conversations with design teams, students were able to access various project documents that had been submitted for LEED certification review. The students were asked to approach the projects through the lens of the Integrated Design Process and to analyze the long-term prospects for design effectiveness in achieving the human, ecological, and economic aspects of sustainability. To complete course assignments, they needed to gain not only a strong awareness of Jordan's environment but also an interdisciplinary perspective on many aspects of the construction and building operation context. They engaged with a diverse community of international professionals representing multiple disciplines,

LEED BD+C V4

Indoor Environmental Quality (EQ)		**16**
Prereq	Minimum Indoor Air Quality Performance	Required
Prereq	Environmental Tobacco Smoke Control	Required
Credit	Enhanced Indoor Air Quality Strategies	2
Credit	Low-Emitting Materials	3
Credit	Construction Indoor Air Quality Management Plan	1
Credit	Indoor Air Quality Assessment	2
Credit	Thermal Comfort	1
Credit	Interior Lighting	2
Credit	Daylight	3
Credit	Quality Views	1
Credit	Acoustic Performance	1

Activity: Health and Wellness aligned with LEED EQ and applicability in MENA region

1. Investigate / collect / search LEED Jordan GBC Gap Analysis (2012) indoor environmental quality outcomes 2017. 5 years, in Jordan.
    - Interviews (authors, users, developers, architects, engineers)
    - Survey (authors, users, developers, Architex, engineers, design industry)
    - Publications (Indoor environmental quality = equal health and wellness.
2. Compile Information
    - Create priorities (see gap analysis)
    - Quantitative and Qualitative approach
3. Identify strengths and weaknesses in analysis after steps 1 and 2 (prioritize)
4. Identify place-based ideologies – shift in mindset, barriers, etc.
5. Draw conclusion for each LEED V4 EQ as applicable to LEED 2009 and revise based on outcomes.
6. Write an updated version of the analysis of the LEED EQ chapter (gap analysis) (credit by credit) based on current conditions and research outcomes – through the lens of V4 and research outcomes.

Fig. 2 Example course assignment: Green Building Council's Leadership in Energy and Environmental Design (LEED) indoor environmental issues in Jordan

ranging from engineers, to legislators, to community planners, to architects, and to facility managers. They also met with building occupants to ask about their experiences as users and inhabitants of the sustainably designed environments.

Outcomes and Conclusion

The goal of short-term international and interdisciplinary study experiences such as the Jordan tour described in this paper is to open pathways for discussion and understanding among professionals from many different backgrounds. The students who participated in this course were exposed to “real-world” challenges in sustainable design in the international context, encouraging them to expand their career horizons and to think more broadly about the purposes and practices of their chosen profession. The “real-world” interdisciplinary experience was transformational for students. Students’ reflective feedback and course evaluation on the experience was strongly positive and indicated that the course achieved its intended purpose. For example, one student wrote anonymously:

> The Jordan Study Tour and the Jordan Green Building Council gave us many great opportunities. One of the many included being able to talk to professionals who have worked in Jordan and understand the challenges and benefits of building and designing in Jordan as well as how the locals think and react to various situations. Many people of Jordan do not see the benefits of designing in a way that benefits the environment. That way of thinking isn’t as common among most Jordanians. Although if they see the financial benefits of sustainable design or hear positive reactions from others about their experiences they start to show interest in the subject. The biggest barrier appears to be getting people interested and understanding the benefits they would receive if they designed with the environment in mind.

What is most notable in this response is that the student has come to understand the central importance of cultural engagement and intercultural sensitivities in the context of the Bennett scale (DMIS), demonstrating an “Acceptance of Differences” in achieving positive sustainability outcomes in the international context, and is able to respectfully describe differences in cultural viewpoints as well as opportunities for constructive dialogue.

At the end of the study tour, the students participated in a closing session with industry leaders in Jordan, sharing their experiences and building on each other’s expertise in the service of achieving common goals. The students reported to the industry leaders their analysis of the feasibility of the current state of sustainability design and development in Jordan and compared these assessments to a “gap analysis” previously published by the JordanGBC. The subsequent students’ reflections on this experience described the impact of the study tour activities, the IDP process, and a pointed concern for designing to local conditions:

> The conclusion to be made after reading the gap analysis and visiting Jordan is that they have the opportunity to design holistically and see each design as a unique opportunity to achieve occupancy health and happiness as well as utilize site and building orientation for optimal performance and use.

> The gap analysis states that mechanical systems are typically for the building and designed in a way that the users do not have control of. One method for individual comfort is for users to bring their own heaters and fans. Some windows are operable but due to climate, since Jordan’s outside conditions are dusty, it is not recommended to open windows. However, implementation is possible if solutions are made early in the design phase. This requires the project team to participate in an integrated design process.

The designers of tomorrow must be able to navigate the needs of local contexts while also maintaining a nuanced global perspective by developing a higher level of cultural sensitivities. International and interdisciplinary educational opportunities are an ideal way to promote this outlook. It is up to us as instructors to familiarize ourselves with the importance of international programs and to identify safe and effective ways to help students "learn by experience" (Kolb, 2015). Collaborative engagement with teams that are simultaneously international and interdisciplinary can provide a solid framework for such educational opportunities, demonstrating to students how to effectively engage in teaching, learning, and professional practice in our current era of globalization. Design leadership at the global scale is essential and urgent in today's world. Through immersive educational experiences, students can prepare themselves to make practical strides toward a healthier society and planet.

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Developing a Rubric for Teaching and Assessing Design Thinking Across the Curriculum

Wendy Friedmeyer

Introduction

Design thinking is often defined as the process by which designers work. Over the past two decades, the ownership of design thinking has moved beyond just use by designers, becoming a buzzword for business and education. Roger Martin, in "Business of Design" (2005), describes a new "design economy" (p. 23). He says in order to compete, American companies need to innovate and use their imaginations to create new products. Linear thinking business people will need to think like designers. Educational research shows how design thinking results in the kinds of learning described as twenty-first-century skills; "art and design education hold a unique role in preparing the kinds of innovative, balanced, synthetic creators and thinkers needed for the 21st Century" (Ingalls Vanada, 2014, p. 21).

However, implementing design thinking within K-12 curriculum hit a roadblock. Art teachers, trained in some elements of design, were not experts, and university courses are often restricted to majors in design, so there seemed to be no opportunity to expand K-12 art education to include design (Davis, 2004). In introducing design thinking to non-art classrooms, teachers embraced or rejected the idea, depending on their professional development opportunities, personal experience, and curriculum development support (Rotherham & Willingham, 2009). This leaves any integration of this potential method for teaching twenty-first-century skills at risk and prompts the question: Do K-12 teachers need to be experts in design to use design thinking? Could design thinking be used to deliver standards-based curriculum and allow for standards-based assessment without requiring teachers to be designers? This paper examines one example of an interdisciplinary design thinking

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integration project undertaken to explore this problem of implementation and discusses lessons learned.

What I am calling design thinking can be described as how designers use a process to do their work and solve problems in their disciplines. Architects, engineers, graphic designers, and fashion designers are all trained in a design process. There are many versions of design processes, including the ADDIE model (analysis, design, development, implementation, and evaluation), the LAUNCH model (look, listen, and learn; ask lots of questions; understand the problem or process; navigate ideas; create; highlight what is working and failing; launch!) (Spencer & Juliani, 2016), and the IDEO model (emphasize, define, ideate, prototype, test) (Raz, 2017). For my purposes, the design process "includes these aspects: identifying and defining a problem, gathering and analyzing information, determining performance criteria for successful solutions, generating alternative solutions and building prototypes, evaluating and selecting appropriate solutions, implementing choices, and evaluating outcomes" (Davis, 3, 1999). Each of these models owes a nod to Bloom's taxonomy, in which cognitive processes are organized from the simple to complex. Bloom's taxonomy describes the cognitive process as acquiring knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Krathwohl's revised taxonomy (2002) includes steps that more closely resemble the design thinking process designers use in their work: remember, understand, apply, analyze, evaluate, and create. Understanding the cognitive processes involved in design thinking both demonstrates the value of design thinking and highlights areas for improvement as this project will show.

Why Integrate Design Thinking into K-12 Education?

The design process I am modeling takes the current state of the product into account and questions the solutions to any problem presented. This kind of thinking teaches students to think sideways, rather than always in a straight line; "through design problems, children learn to think laterally, generating many alternatives rather than progressing through a linear process to the right answer" (Davis, 1998, p. 57). Lateral thinking "seeks to disrupt patterns so that the information released may reform itself into new and better patterns" (DeBono, 1969). When it is not clear what jobs these young people may hold in 20 years, this kind of creative thinking is necessary to succeed.

Design thinking is a method to teach problem solving skills, teamwork, and communication skills as well as engaging in aspects of art making. Razzouk and Shute (2012) note students of design are encouraged to be creative while also learning how to question and find solutions in other areas of their life and studies; "improving students' design thinking skills through having them apply processes and methods that designers use to ideate and help them experience how designers approach problems to try to solve them, students will be more ready to face problems, think outside of the box, and come up with innovative solutions" (p. 343). In addition, thinking like a designer can prepare students and business people for the rest of the twenty-first century and "may better prepare them to deal with difficult situations and to solve complex problems in school, in their careers, and in life in general" (Razzouk & Shute, 2012, p. 343). "The Framework for 21st Century Learning" enumerates the important skills determined to be necessary for twenty-first-century citizens. These skills, "innovation and creativity, flexibility, and adaptability, collaboration and working as a member of a team, problem solving and critical thinking and communication," are activated in the process designers and engineers use in their work; "teaching design in K-12 schools is an effective approach for students to learn content and develop 21st century skills through integrated study" (Vande Zande, 2011, p. 28). Research shows that design thinking "focuses on developing children's creative confidence" (Carroll et al., 2010, p. 38). Researchers studied the effects of a design curriculum implemented in a middle school geography class. Their results showed how the students saw themselves as part of the solution. This understanding develops meta-cognitive skills. It also demonstrated how students took risks, expressed creative confidence, and collaborated with other students.

The work of designers has become increasingly concerned with social issues and human systems (Cassim, 2013). In addition, designers need to keep their "profession relevant and articulate new areas of design in order to deal effectively with change and complexity in the twenty-first century" (p. 192), and one of these new areas, design thinking, "has surfaced as an important design tool for skill for innovation… and social innovation" (p. 192). The design process can be seen as an "inclusive approach to manage social innovation" (p. 200), and students, "through practice and the opportunity to explore real world problems… are able to nurture and hone their ways of thinking and advance their practice" (p. 201). While Cassim focuses on students studying design at the university level, these ideas can also apply to K-12 students. He describes design thinking as a "methodology of relevance," describing it as playing "a strategic role in framing and answering many of the social, economic and environmental problems with which the country (South Africa, in this case, but certainly globally) is faced" (p. 201).

Problems in Implementing Design Thinking in K-12 Education

There are problems implementing these new ideas in K-12 schools and in organizations. "The eagerness to adopt and apply these design practices in other fields has created a sudden demand for clear and definite knowledge about design thinking (including a definition and a toolbox)" (Dorst, 2011, p. 521), but designers are professionals, considered experts, and students and companies are novices, and "designing is conceived as a complex, personal, creative, and open-ended skill" (van Dooren et al., 2013, p. 2). Designers do not see the design process as a set of tasks to be completed, but as a whole they have mastered. In order to teach the design process, "making explicit and becoming aware how to do it are essential. In that respect it is similar to learning a sport" (van Dooren et al., 2013, p. 2). Like professional athletes, designers have spent hours practicing their skills; "the major difference between experts and novices is that experts have accumulated a large number of examples of problems and solutions in a specific domain of interest" (Razzouk & Shute, 2012, p. 338). However, that does not mean a youth team cannot still play the game of baseball, or a seventh-grade classroom cannot complete a design project.

Goals and Rubric Development

In 2016, I was a part of an Art and Design Professional Learning Community (PLC) as a seventh-grade Media Literacy teacher at a suburban middle school in the 11th largest school district in the state. The school is in a diverse community with varied housing, corporate offices, and service businesses. The demographics are similar to many suburban schools in the area: 63% White, 11.5% Asian, 8.5% Hispanic, 10.6% Black, 0.1% Hawaiian/Pacific Islander, 0.4% Native American, and 5.6% two or more categories. It is important to note that 29% of the students are eligible for Free or Reduced Lunch (FRL), 10% receive special education services, and 5% speak English as a second language. The languages spoken other than English are most often Spanish, Somali, and Hmong. It is also important to note that the Asian and Black categories include recent immigrants as well as more established cultures.

Before the term started, the PLC met with the principal to discuss ideas for the Art and Design and Media Literacy (part of English/Language Arts) curriculum. The conversation was inspired by the book *Launch: Using design thinking to boost creativity and bring out the maker in every student*, by John Spencer and A.J. Juliani. Written by teachers turned consultants, *Launch* provides lessons and ideas to introduce students to design thinking. The *Launch* idea was introduced to our principal in a professional development session. Our school had also just added a Maker Lab, and the administration was very interested in having it used. The principal shared a possible three-step design process (inspiration, ideation, and implementation) based on yet another model, IDEO (inspiration, ideation, and iteration). Although there was a slight disagreement of pragmatics for the term "inspiration," the team decided to adopt the idea of using the three "I"s in each of their classrooms, choosing to use investigation, ideation, and implementation as an easy-to-remember set of steps.

Launch suggests projects need to be flexible (Spencer & Juliani, 2016), and teachers may need freedom from high-stakes testing to make it work. Our goal was not just to provide a lesson after testing, as teachers often resorted to doing, and as was even recommended, "if there is heavy pressure connected to upcoming standardized tests, it might work best to do a design project afterward" (222), but rather use our current curriculum, enhancing it by tying design thinking methods to our standards-based lessons. With the standards, district-wide goals, and PLC goals to meet, we felt we needed a tool for planning and assessing lessons and student learning.

In addition, objectives for courses needed to be met and lesson one needed to be completed before lesson two could begin. There were also expectations that students would understand topics necessary for eighth grade. The focus standards for Media Literacy were:

> 7.7.7.7 – Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.
>
> 7.7.8.8 – Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
>
> 7.9.1.1 – Engage effectively in a range of collaborative discussions (one-on-one, in groups and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.

These standards fit the design thinking process in a few different ways. Research and collaboration were two key areas that each unit would cover.

Because of all these constraints and requirements, it was necessary for lessons to be mapped out while still allowing for some flexibility, additional research, and prototyping. Using the general principles of the design process, we expanded and amended the three "I"s proposed by the principal into a rubric detailing 12 steps in the design process with action steps for the students to address. Each step of the rubric would be addressed in a lesson, and each action step was accompanied by a point range and room for documenting what each student had done to complete that step and earn the points they assigned themselves.

The questions the students considered were as follows:

Investigation

1. I asked high-level questions.
2. I researched from a variety of sources.
3. I gained empathy and made connections.
4. I defined and understood the problem.

Ideation

1. I generated ideas to solve the problem.
2. I worked collaboratively with my team.
3. I reflected and chose the best idea based on the criteria.
4. I created a quality and detailed prototype.

Implementation

1. I gave and received feedback from peers, teacher, and target audience.
2. I refined and tested my prototype based on this feedback.
3. I built the final product based on set criteria.
4. I presented my project based on set criteria.

In addition to meeting state education standards, our PLC had to create what was called an Integrated Site Improvement and Innovation Plan (ISIIP) goal. We described ours as follows: "We want students to think like designers. Specifically, we want students to wonder, ask questions, and independently find their answer. We will utilize the three-step Design Process (Investigation, Ideation, and Implementation) as the foundation for each challenge." We also had a goal for our interdisciplinary PLC. This is exactly how it was written in the referenced plan "80% of students will be able to demonstrate proficiency implementing the design process as is measured by the rubric score of 9 out 12."

Data and Analysis

We created a pre- and posttest using design challenges and a rubric to determine whether students could understand and implement the design process. In addition to the pre- and posttest, we also incorporated unit-long design challenges that imbedded the design process as part of the assessment and challenge.

Two art teachers created a pretest using a Wonder Day Challenge. A Wonder Day Challenge is a design challenge that only takes one class period. Students reviewed their notes and reflections from that challenge and assessed their understanding using the rubric. The other art teacher had students reflect using the design process rubric at the end of their first project. He also incorporated a 2-day pre- and post-Wonder Day Challenge.

We determined that, overall, the more we could prove how flexible the design process is with our different content areas and student populations, the more dynamic our data sharing/conversation would be. We acknowledged that we would find differences in our testing process, but those would be surmountable because design thinking was the common thread between our different disciplines and classrooms.

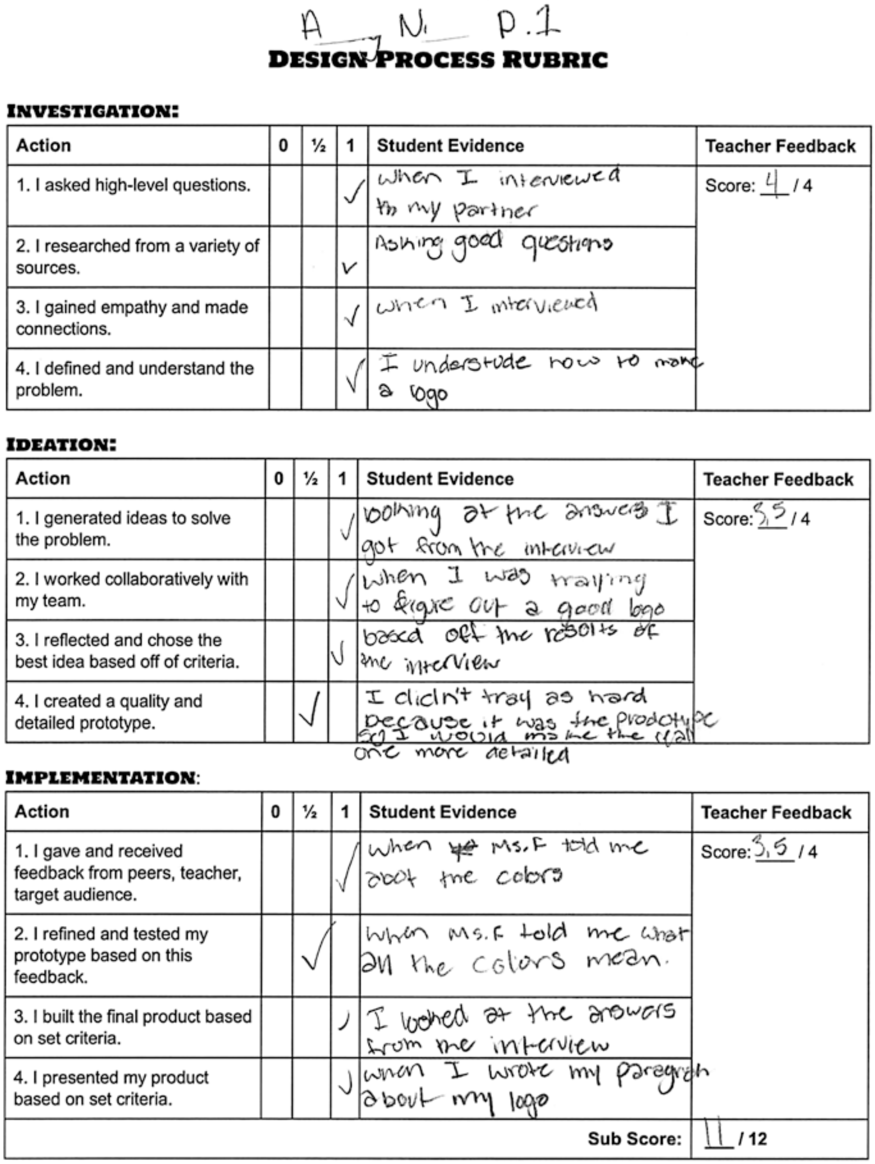
For example, in the Media Literacy classes, the students used the rubric to self-assess their understanding of the principles of the design process after a hands-on project using the design process. The first unit of the course, *Brand Your Classmates: Introduce and Develop a Logo for a Partner*, introduced students to logos and the qualities of a good logo. It also served to introduce the students to one another. Each element of the design process rubric was scaffolded in the lesson, but students were not introduced to the rubric worksheet until after the lesson. The rubric was used as a pretest, creating a baseline for measuring understanding over the course of the semester. Relying upon the lesson they had just completed, students reviewed the steps of the process and assessed their actions on each step with a score of zero (I did not complete this task) to one (I completed this task to the best of my abilities). Some students clearly understood how asking interview questions helped them gain empathy and how making changes to the colors on their logo after receiving feedback was refining their prototype (Fig. 1). Other students did not make the connection. We followed up the first unit with a lesson introducing the design process, and we also incorporated unit-long design challenges that imbedded the design process as part of the assessment and challenge.

Although we had intended to integrate the design process into existing curriculum, our team ended up designing much of our curriculum from scratch, which, although daunting at times, allowed us to incorporate the Maker Lab and repeatedly apply the design process to lessons. These new lessons included the Art and Design Teeter Totter and a Water Bottle Vinyl Cut Logo unit that incorporated tutorials on the vinyl cutter, as well as the Media Literacy Advertising unit.

After the first term (all teachers taught semester classes), we had met our goal, in that at least 80% of students were demonstrating proficiency and understood and could implement the design process based on the rubric grading. However, certain populations, including nearly half of the SpEd/504 students, were not demonstrating proficiency when it came to successfully completing the actions on the rubric. The design process provides opportunities for higher-level thinking that some of our populations (such as students with disabilities) need to continue to develop. Although the data may not show full student proficiency, groups such as the SpEd/504 showed growth and could demonstrate their mastery through the unit-long design challenges that were modified and scaffolded to their ability. While not all students reached 80% proficiency, some students showed remarkable growth, gaining 50 percentage points over the semester. When students undertake the process with a variety of background experiences, their ability to reach proficiency in one semester is stymied, but the growth in these particular students is a sign of success.

Although there is known benefit to learning from self-reflection and critique, we were interested in creating a more concrete way of measuring students' knowledge of the design process after the first semester. While we continued to use the rubric for the projects, we used a multiple-choice quiz to measure understanding of terms and steps used in the design process, administered to the students at the beginning and end of the second semester.

Based upon our pretest data gathered at the beginning of the second semester, 67% of our students were familiar with the design process. By the second half of the year, many students had been exposed to design thinking in one of their classes (either Art or Media Literacy). Knowing students were familiar with the design process, we wanted to focus our efforts on helping students think like designers and develop higher-level thinking skills. We measured this through our design process rubric, product development, and presentation. Judging by our posttest results and student projects, our focus was successful. Data confirmed that 85% of our students were proficient (scored 8 out of 10) on the design process posttest.



A N P.1

DESIGN PROCESS RUBRIC

INVESTIGATION:

Action	0	½	1	Student Evidence	Teacher Feedback
1. I asked high-level questions.			√	When I interviewed ~~to~~ my partner	Score: 4 / 4
2. I researched from a variety of sources.			√	Asking good questions	
3. I gained empathy and made connections.			√	when I interviewed	
4. I defined and understand the problem.			√	I understode how to make a logo	

IDEATION:

Action	0	½	1	Student Evidence	Teacher Feedback
1. I generated ideas to solve the problem.			√	looking at the answers I got from the interview	Score: 3.5 / 4
2. I worked collaboratively with my team.			√	when I was traying to figure out a good logo	
3. I reflected and chose the best idea based off of criteria.			√	based off the results of the interview	
4. I created a quality and detailed prototype.		√		I didn't tray as hard because it was the prodotype so I would make the real one more detailed	

IMPLEMENTATION:

Action	0	½	1	Student Evidence	Teacher Feedback
1. I gave and received feedback from peers, teacher, target audience.			√	when ~~we~~ Ms.F told me about the colors	Score: 3.5 / 4
2. I refined and tested my prototype based on this feedback.		√		When Ms.F told me what all the colors mean.	
3. I built the final product based on set criteria.			√	I looked at the answers from the interview	
4. I presented my product based on set criteria.			√	when I wrote my paragraph about my logo	
				Sub Score:	11 / 12

Fig. 1 Rubric worksheet completed by a student

Challenges

Each lesson was a challenge for the teachers, as very few lessons using the design process had been used previously in the curriculum. One issue developed as we started to try to use the Maker Lab as an element of our lessons. The students started off by using SVG-Edit (a web-based design software available for free and accessible on the students' Chromebooks) for 2 days to outline logo designs. Then we moved to the Maker Lab for 2 days to work in Corel Draw and to use the vinyl cutters. There was a lot of waiting with 33 preteen students learning new software and new technology. In the end, we cut three designs out of cardstock. We would like to use Corel Draw as a tool, and in the future, seventh- and eighth-grade students may have learned enough Corel Draw in sixth grade to complete the assignment, but even with additional training on the part of the students and the teachers, the time spent troubleshooting in the lab might still take away from the lesson.

If we want to foster our students to become "curious, self-sufficient, risk-takers," we would like to focus first on the beginning stage of the design process: investigation. We found that students had difficulty with that first step, where researching a topic by more than one means was new to students. In the future, we want to focus on research strategies (mind-web, chart, knowledge map, etc.) that students can access, no matter their background, and then be able to utilize for any design challenge presented.

Conclusions and Next Steps

Creating and using a rubric helped our PLC both integrate design thinking into our lessons across the disciplines and assess student understanding of the concepts. Breaking down the design thinking process into 3 and then 12 parts made applying each concept to both product design and a research paper equally facile. Using the design thinking process provided students with the practice on each skill needed and required by the standards while also providing scaffolding for the feedback and presentation steps. This gave a real-life feel to each process in considering fellow student/client needs and using a shared presentation project to make connections and provide information to classmates in a student-led session. Using the rubric allowed our PLC to customize lessons for our respective disciplines, without requiring students to be design experts to complete each task. In addition, the rubric provided an outline for an assessment tool that helped us provide the numerical evaluation of student learning that our school required.

K-12 teachers do not need to be experts in design to use the design process. However, some practice helps teachers understand the steps of the design process and what hurdles students face when receiving feedback or iterating when they have only solved problems with single solutions in the past. Students practiced research and collaboration skills, among others, in each design-based project. Using the design process made them slow down and address each aspect of their projects, resulting in a more well-formed final result. While additional training in some of the tools we wished to use would have been helpful, the design process rubric allowed inexperienced teachers to implement design thinking in their classrooms with some success.

Providing pre-service teachers with some hands-on experience would enhance the use of the design process and its learning outcomes across the curriculum, but while developing a way to do so, practicing educators allowed to experiment with the design process using a rubric can enhance their curriculum with measurable positive outcomes.

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Teaching Design to Public Health Majors: A Design Case of an Undergraduate Interdisciplinary Course

Victoria Abramenka-Lachheb, Ahmed Lachheb, and Gamze Ozogul

Background of the Course

Multimedia in Instructional Technology (R341) is a three-credit-hour course offered in the School of Education at Indiana University Bloomington. The course emphasizes multimedia design and production skills to create instructional materials that address particular public health problems (e.g., teaching college students about sexually transmitted diseases, promoting healthy behaviors among vulnerable populations, etc.). Students in R341 are expected to demonstrate mastery of multimedia design and production skills through the design of multimedia artifacts, such as infographics, instructional videos, podcasts, print materials, and websites, that are aligned with the objectives of the broader instructional solution designed to address a particular public health problem, in a specific context. The primary learning objectives of this course are:

- Describe a series of instructional and graphic design methods and principles.
- Formulate objectives, potential impact, and outcomes of instructional materials.
- Apply design processes in the development of instructional materials for target audiences.
- Produce effective instructional materials to target audiences.

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Interdisciplinary Nature of the Course

At the Department of Instructional Systems Technology (IST) in the School of Education —where we work as instructors (Abramenka-Lachheb and Lachheb) and faculty (Dr. Ozogul)—we prepare faculty members, instructional designers, trainers, and educational technology practitioners to *improve human learning and performance in diverse contexts*. This preparation entails teaching instructional design, educational technology integration, and multimedia design and production skills. These skills are the core competencies that students majoring in IST—or students who take IST courses as a part of their teacher education degree program—need to acquire.

Upon learning that students in public health were the only students taking this course, we naturally asked: "Why do public health majors need to take an IST design course?" This question begged a more important question in our minds: "How does public health intersect with education and IST?" We asked these questions because IST—or education in general—and public health are not traditionally neighboring fields. As designers, we had to understand how public health professionals engage in their profession differently than instructional designers before we embarked on re-designing R341.

Conducting research and holding conversations with public health faculty, IST faculty, former R341 students (who took an earlier version of the course), and other stakeholders allowed us to answer these questions. We found that earlier versions of this course had primarily focused on purely technical and how-to procedures of using computer software to develop media. Therefore, our task was to redesign the course. We recognized that multimedia design and production skills are among the essential skills that public health practitioners need to possess (Public Health Foundation, 2014), owing the critical role these skills play in (1) educating the public about health and (2) training employees in public health organizations (National Center for Biotechnology Information, 2002). We also found that data solicited from alumni of a School of Public Health highlighted these skills as "mandatory to have among public health job candidates." Thus, acquiring these skills will enhance the employment prospects of public health majors. Additionally, we found that accreditation agencies, such as the Council on Education for Public Health (CEPH), which accredits School of Public Health graduate and undergraduate programs, require public health courses to address competencies focusing on public health program planning, which entails designing instructional materials using multimedia design and production skills (CEPH, 2019).

Teaching instructional design, educational technology integration, and multimedia design and production skills in public health contexts forms the interdisciplinary nature of the course and guided our thinking on how to design the course in an interdisciplinary way. For us, an interdisciplinary course means that two or more academic fields—that are not traditionally neighboring fields—are combined into one area of practice because each field has practices, tools, methods, and approaches that can be shared together for a more significant benefit. Public health relies heavily

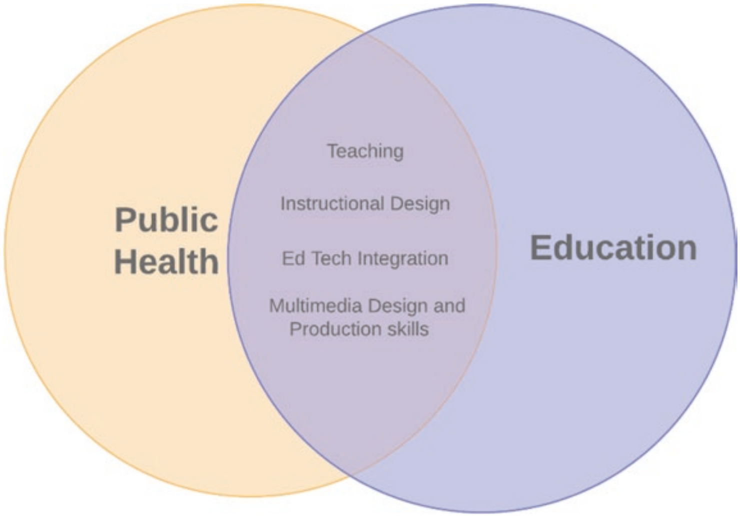


Fig. 1 A simplified Venn diagram to show our understanding of the interdisciplinary nature of Multimedia in Instructional Technology (R341) course

on educational strategies, and thus we think that multimedia design and production skills that are taught traditionally in educational contexts become equally relevant to the field of public health (see Fig. 1).

Design Team: Instructors/Designers and Mentor

Ahmed Lachheb was tasked first to lead the design of R341 since he was scheduled to teach it in the 2016–2017 academic year, and Victoria Abramenka-Lachheb was scheduled to teach it in the 2017–2019 academic years. Overwhelmed with the intricate design project, Ahmed reached out to Victoria and Dr. Ozogul to form a design team because of their experience and their interest in doing instructional design work of this interdisciplinary nature.

- **Ahmed Lachheb** has a background in instructional design and education, having previously earned a Bachelor's in English and a Master's in Educational Technology. His design experience started in 2010 while getting his master's, serving as a graduate assistant. Upon graduation and before his doctoral work in instructional systems technology, Ahmed worked as an instructional design and technology specialist. Since starting his doctoral studies, he has been studying instructional design, practicing instructional design—at the University and through independent consulting work—and teaching educational technology and instructional design courses at both graduate and undergraduate levels.

- **Victoria Abramenka-Lachheb** has a background in higher education, communication, and instructional technology, having previously earned both a Bachelor's and Master's in Communication and working as a university instructor and an instructional technologist. Her design experience started in 2013 when she taught and designed online courses in communications, prior to her doctoral work in the field of instructional systems technology. Since she started her doctoral studies, she has been studying instructional design, practicing instructional design at the School of Public Health and teaching educational technology and instructional design courses at both graduate and undergraduate levels.
- **Dr. Gamze Ozogul** has a background in Curriculum and Instruction (BS) and Computer Education and Instructional Technology (MS, PhD). Her design experience started in 1999 while earning her bachelor's degree. Dr. Ozogul worked as an evaluation consultant, a research scientist, and a director of measurement and evaluation for national and international organizations. Since joining the Department of Instructional Systems Technology, Dr. Ozogul has been teaching instructional design, conducting research on instructional design for online learning, and serving the needs of international organizations through evaluation consulting work. While serving as a mentor to both Victoria and Ahmed, Dr. Ozogul has made a significant contribution to the design of the course through her feedback, encouraging the course instructors (Ahmed and Victoria) to make the course an interesting learning experience.

Iteration One: Introducing First Features of Interdisciplinarity

When we started designing the course, we spent a significant amount of time reading about the field of public health in order to discover the primary missions of public health and the career paths available within this field. We consider this dive into public health literature a crucial step in educating ourselves about the field and informing our design decisions. As we started framing our understanding of public health, we found many striking similarities between methods used in IST and public health, such as assessment and evaluation, design of educational campaigns, etc.

We further explored websites of major public health professional organizations, including the Centers for Disease Control and Prevention (CDC), American Public Health Association (APHA), and the U.S. Department of Health and Human Services (HSS). We also consulted with public health faculty members, who had extensive professional experience in the field of public health and expertise teaching public health courses. Learning more about the field of public health prompted us to take specific design actions to make this course interdisciplinary. These included:

- *Introducing instructional design as an approach to solve particular public health problems*

- *Introducing principles and best practices of design to apply to multimedia design in the context of public health*
- *Introducing design guidelines from prominent public health organization to apply to multimedia design and production in public health*

Instructional Design as an Approach to Solve Public Health Problems

We introduced instructional design to public health students as *a process of making learning efficient, effective, and less difficult*. While this definition is generic, we emphasized that this process could apply to public health problems in which a group of people lacked knowledge or a specific type of skills pertaining to a particular health issue. Thus, designing instruction for those individuals would be beneficial and could partially or entirely solve the given public health problem. We designed cases that address these particular problems based on our review of public health literature, as mentioned earlier. This research also allowed us to provide examples of instructional design in the context of public health, which had not traditionally been thought of as "instructional design." For example, the 1986 Koop Papers—which were congressionally mandated brochures on AIDS sent to every American household—was an example of an instructional design artifact that addressed a particular public health problem among communities, that is, a lack of knowledge about AIDS as a new epidemic (Fig. 2).

In our lessons, we highlighted that instructional design is an approach that should not be applied to all kinds of public health problems. We introduced examples of public health policies that were put forth to address particular public health problems, such as tobacco consumption (e.g., raising taxes on tobacco) and not having health insurance (e.g., Affordable Care Act). We also highlighted, through cases and

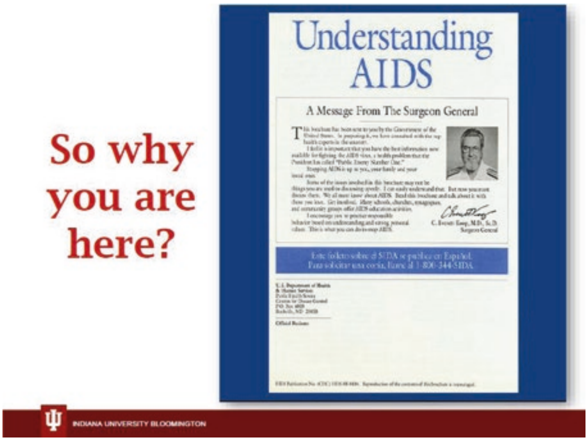


Fig. 2 A screenshot of the introductory lesson on instructional design and how it applies to public health featuring the famous Koop AIDS education campaign

class discussions, the limitation of instructional design to address other public health problems, namely, that instruction is not the only solution to address a particular public health problem (Fig. 3).

Different Principles of Design to Apply to Different Multimedia Design in Public Health

Further, we introduced design principles that apply to print and digital media, such as CARP (Contrast, Alignment, Repetition, and Proximity principles), rule of thirds, color theory, and "best practices" for video production (lighting, camera position, etc.) and audio production (background noise, music, tone, enunciation, microphone position, etc.). When introducing these design principles, we used examples of instructional materials from the public health context. Such materials included print and digital media produced by major public health organizations (Figs. 4 and 5).

Design Guidelines from Prominent Public Health Organization

We also introduced design guidelines from major public health organizations, such as the Centers for Disease Control (CDC) and the Office of Disease Prevention and Health Promotion (ODPHP), which we found when we were researching how multimedia is used in public health. For instance, we found a CDC's guide for producing

Safety in the Workplace

(Adapted from *Designing Effective Instruction,* by Gary R. Morrison, Steven M. Ross, Jerrold E. Kemp & Howard Kalman)

In addition to mentioning the new computer controls, Josh stated that production speed had increased considerably during the previous six months. "*Due to demands and expanding our work into other counties in the states, we have had to increase our line speed; a lot of our people have been angry they have to work harder. Some of my people don't realize they are getting careless while they are working. Now that I think about it, it seems like a lot of the old-timers have trouble trying to keep up with the new pace. I'm sure some training would help all my employees.*"

Fig. 3 An excerpt from a case—adapted from *Designing Effective Instruction*, by Gary R. Morrison, Steven M. Ross, Jerrold E. Kemp, and Howard Kalman—that deals with "safety in the workplace," with modification to show that an increase of the workforce (as production demand increases) could be an effective solution to reduce work accidents. Thus, training is not a solution

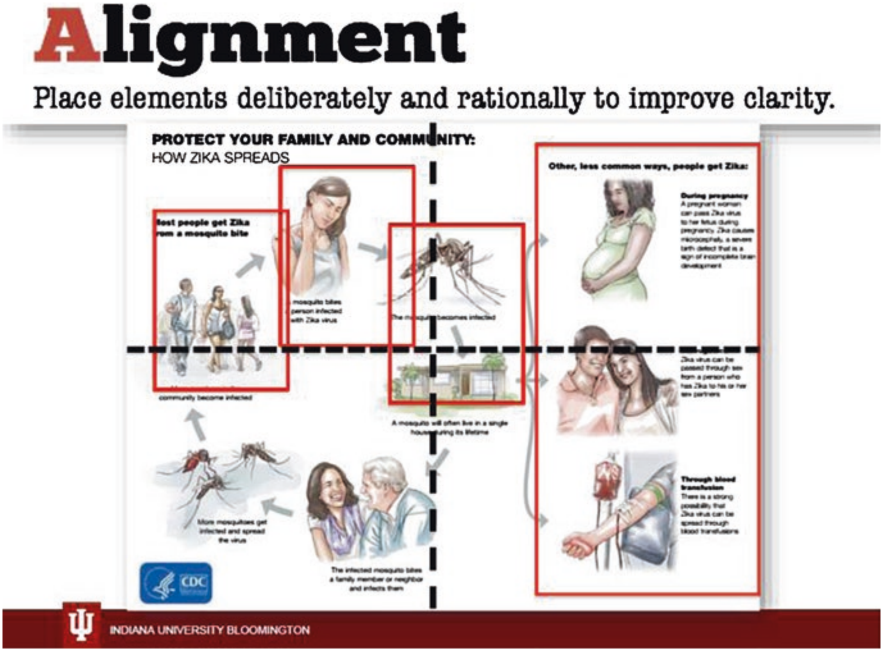


Fig. 4 A screenshot from a lesson that covers CARP principles and showcases its correct and incorrect application in designing print and digital instructional materials in the context of public health

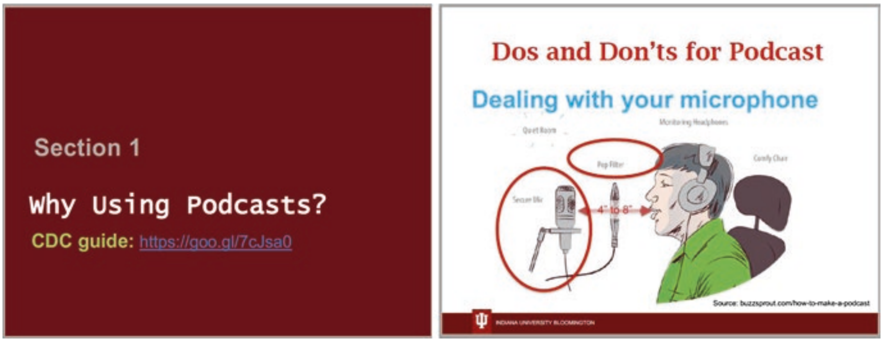
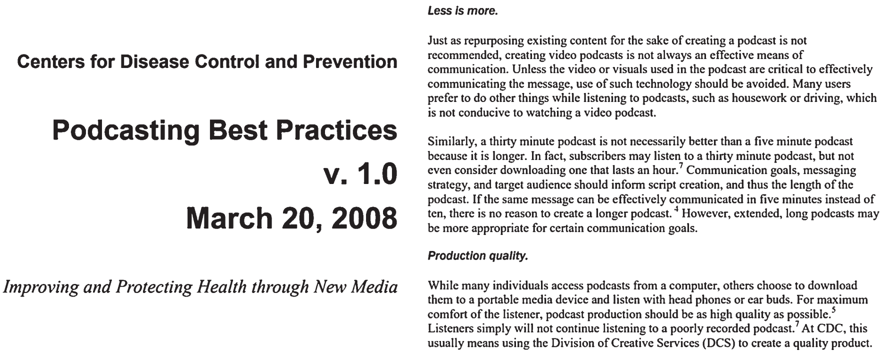


Fig. 5 Screenshots from a lesson that covers audio production principles and showcases best practices for podcast recording to ensure high-quality podcasts in the context of public health

podcasts in public health (Fig. 6) and elaborated tutorials on how to design public health websites (Fig. 7). We find that these guidelines speak genuinely to the nature of multimedia design and production in public health and offer design considerations that other fields of design—such as IST—consider to be valid and valuable.


Centers for Disease Control and Prevention

Podcasting Best Practices

v. 1.0

March 20, 2008

Improving and Protecting Health through New Media

Less is more.

Just as repurposing existing content for the sake of creating a podcast is not recommended, creating video podcasts is not always an effective means of communication. Unless the video or visuals used in the podcast are critical to effectively communicating the message, use of such technology should be avoided. Many users prefer to do other things while listening to podcasts, such as housework or driving, which is not conducive to watching a video podcast.

Similarly, a thirty minute podcast is not necessarily better than a five minute podcast because it is longer. In fact, subscribers may listen to a thirty minute podcast, but not even consider downloading one that lasts an hour.[7] Communication goals, messaging strategy, and target audience should inform script creation, and thus the length of the podcast. If the same message can be effectively communicated in five minutes instead of ten, there is no reason to create a longer podcast.[4] However, extended, long podcasts may be more appropriate for certain communication goals.

Production quality.

While many individuals access podcasts from a computer, others choose to download them to a portable media device and listen with head phones or ear buds. For maximum comfort of the listener, podcast production should be as high quality as possible.[5] Listeners simply will not continue listening to a poorly recorded podcast.[7] At CDC, this usually means using the Division of Creative Services (DCS) to create a quality product.

Fig. 6 Screenshots from the CDC's guide on podcasting (accessible on this link: https://goo.gl/7cJsa0)

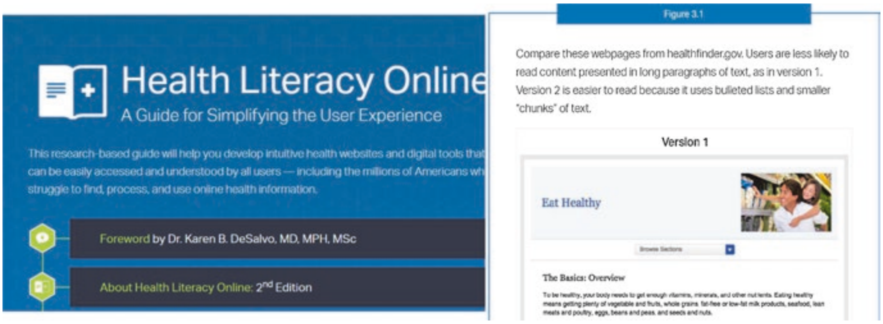


Fig. 7 Screenshots from the ODPHP's guide on designing public health websites that target health literacy (accessible on this link: https://health.gov/healthliteracyonline/)

Why Introducing First Features of Interdisciplinarity?

We think that introducing the aforementioned characteristics of interdisciplinarity stems from our firm belief that design, regardless of the field, is relevant and is a powerful method for change and problem-solving. We think that design, in the broad sense of the word, is the "oldest human tradition" (Nelson & Stolterman, 2012). Thus, making an interdisciplinary course that combines public health and education/instructional systems technology will create a beneficial area of practice that empowers the public health mission and strengthens the value of education and instructional design.

Additionally, we think that introducing the above characteristics of interdisciplinarity was a solid design strategy that aimed to appeal to students' backgrounds in public health, thus motivating them to learn. We find that the approach of relating the course material to students' academic background to be (1) a solid pedagogical practice, particularly when new knowledge and skills are about to be introduced, and (2) to be helpful in emphasizing the interdisciplinary nature of the course.

Design Failures

While Ahmed was teaching the course, he kept reflective notes in which he wrote ideas, thoughts, and insights regarding the design of the course and how it could be improved. Through formal and informal conversations with each other as designers and instructors, we realized that, while we achieved some significant successes, primarily with students' learning gains as evident in their produced artifacts, we were not satisfied with some other aspects of the course. We consider these instances to be our design failures.

First, we realized that introducing instructional design as an approach to solve some public health problems was not well understood. In fact, we discovered later that instructional design is better introduced within the area of public health programming—an approach to solving public health problems within communities based on their actual needs. We found that as a result of not making this connection, students were confused regarding how instructional design could be relevant to the field of public health.

Second, while we relied on examples from public health to introduce design principles, guidelines, and best practices, we found that not all examples were helpful to the students. Further, some of the principles we introduced were either too abstract or too complicated to grasp without tangible examples. In a few cases, the absence of examples made such principles vague, thus hard to adopt by most students who were new to design.

Third, based on students' evaluation and our reflections, we realized that the quality of student's artifacts varied. This variation was sometimes large to the extent that it made us concerned with equity in our design. We found that students' previous practice with design tools and the time they allocated to refine and iterate on their designs were the major factors of the large variability in the quality of their artifacts.

These instances of design failures made us reconsider our design and start a second iteration of the course, focusing on authenticity of assignments and in-class activities, emphasizing design references/exemplars, and allocating more time to design tools demonstrations and in-class practice. We consider these approaches to be effective in strengthening the connection between instructional design and public health program planning, in better explaining design principles, guidelines, and best practices, and in providing equitable practice with design tools.

Iteration 2: Authenticity of Assignments/In-Class Activities, Design References/Exemplars, and Design Tools Demonstration/Practice

Based on the instances of design failure that we recognized, we decided to make significant revisions to the course, thus launching a second-course iteration. These revisions explicitly aimed to tackle the instances of failure, enhance the course design, and provide students with better learning experiences. The specific design actions we took were:

- Contextualizing assignments and in-class activities to make them authentic to public health contexts
- Enhancing the presence of design references/exemplars to better explain design principles, guidelines, and best practices
- Allocating more time for design tools demonstrations and in-class practice

Contextualizing Assignments and In-Class Activities

We contextualized learning activities and multimedia design projects in the area of public health by incorporating public health content, particularly the content related to public health program planning. The course lectures and weekly learning activities were redesigned based on the most current public health issues in which students were currently engaged or would in the future be engaged in. When designing cases for class discussions, we researched the most current or pressing issues in public health on a national, state, and community level, including the opioid crisis in a given state, the creation of dementia-friendly communities, teen pregnancy, vaping and cigarettes, and the promotion of healthy dieting and exercise nationwide. Below is a scenario that was designed for an in-class discussion that demonstrates contextualization:

> According to a new study conducted by the US Environmental Protection Agency and the World Health Organization, high and moderate levels of air pollution are causing an increased risk of diabetes worldwide. According to this new study, cycling is considered the best practice to address this issue. Based on this report, the [your state] State Department of Health plans to start a new program centering on promoting cycling for everyone as daily transport mode. You are leading this project, and you understand that you will need to cooperate with a wide range of stakeholders to design this program. The purpose of this program is two-fold: promote a healthy lifestyle and decrease pollution levels.

In your group, discuss the following questions and write down your ideas:

- What would be your first step(s) in designing this program?
- What kind of information, you think, you would need to move forward with the project?
- What type of educational material would you design for this public health program?

We redesigned all assignments—multimedia design projects—by allowing students to choose any public health-related topic that was meaningful and relatable to them. This feature was not available in the first design iteration. Ultimately, some students decided to work on health issues to which they lost their family members or friends, health issues their family members or friends are currently coping with, or health issues which they had themselves. In addition, students were encouraged to work with a real-life public health organization on the design of health educational materials. Finally, knowing that public health professionals design and develop different types of interventions (e.g., educational, regulatory, or environmental), the assignments were presented to students as if they were working on an educational public health intervention. That is, students created different resources, such as brochures, infographics, instructional videos, podcasts, or websites, as a part of an educational campaign addressing a particular health issue of their choosing. For instance, students worked on projects aimed at promoting positive mental health among college students, raising awareness for the issue of the "Freshmen 15" and how to maintain a healthy lifestyle while in college, addressing sleep deprivation among college students, or sharing information on vaping to adolescents (Fig. 8).

Assignment Description

For creating your 2-3-minute instructional video, you have the following options:

1. Creating a video describing a particular public health issue: select a health issue of a specific target population. First, you will need to select a target population and research what health issue/s they currently have. In your video, you will describe a particular health issue through emphasizing its importance and consequences, as well as suggestions/ways to address it. You can create your instructional video around the same topic as for your infographic. When describing a specific issue, be sure to cite credible sources, such as American Public Health Association, Centers for Disease Control and Prevention, etc.

2. Also, you can create a video to promote healthy behaviors and healthy lifestyle: benefits of a specific diet, benefits of a particular sport, or even a healthy recipe. Your video should be informative and engaging.

When working on your video about a particular health issue, keep in mind the following questions:

- What is your target population?
- What is a health issue?
- Why is it important?
- What are social and behavioral determinants of a health issue?
- What is being done to address a health issue? or What are the ways to solve a health issue?

When working on your video aimed at promoting healthy behaviors and healthy lifestyle, keep in mind the following questions:

- What is your target population?
- What healthy behaviors are you promoting in your video: working out, healthy diet, etc.?
- Why is it important? or What are the benefits of working out, healthy diet, etc. (include facts)?
- Suggestions on how to get started on developing healthy behaviors and healthy lifestyle.

The ultimate goal of your instructional video should be either raising awareness of a particular issue so that a target population can take preventive measures, teaching a procedure, or encouraging a specific target population to improve or maintain positive health behaviors.

Fig. 8 Example of an assignment description where students have to relate projects to the context of public health

Design References/Exemplars

In designing each unit on how to design a particular artifact (e.g., a brochure, video, or infographic), we gathered or asked students to gather examples of artifacts that they can either refer to as "bad or good examples." Each assignment included a collection of exemplary work done by previous students and examples provided by major public health organizations (e.g., Centers for Disease Control and Prevention, American Public Health Association, National Institute of Environmental Health Science, World Health Organization, U.S. Department of Health and Human Services, and U.S. Public Health Service). We also collected examples from local public health organizations and brought these tangible artifacts to the classroom to explore.

1. Below you can see a list of topics that you used for creating your projects. Since most of you will likely continue the same topics, below you can see examples of websites addressing health issues you covered in your materials (brochures, infographics, and instructional videos). Click on your topic to explore different websites.

2. Select one website and critique it from the following perspectives:

Website structure & functions: do you find it easy to use and navigate between pages? Why or why not?

Content: can you describe each page in one short sentence? It is an "FYI" or a "Call to Action" content?

Organization: how is it organized? What logic is used to organize the website?

Use this Paddlet board to write down your ideas to share them with the class:
https://padlet.com/vabramen1/3w66jsdbiraq

- Stress Management and Prevention
- Healthy Eating and Diet
- Mental Health
- Sleep Deprivation
- Smoking
- Wellness and Fitness
- HIV and AIDS
- STDs

Stress Management and Prevention

- Stress Management and Prevention
- Stress Management
- Guided Meditations
- Stress Management Society

Healthy Eating and Diet

- Choose MyPlate
- Verywell Fit

Fig. 9 Example of an in-class public health website analysis activity

The major challenge of looking for such references was to clearly define for ourselves what a good design should look like and why students would find them helpful. First, we identified criteria that characterized a good design based on the topics designed for this course, such as "Does this example use contrast?" or "Are all the elements well organized and aligned?" or "Is it clear for whom the message is designed?" or "Does it convey the message clearly?" To solve this challenge, we carefully studied and analyzed examples of multimedia content on the websites of the above major public health organizations and designed a similar activity for the students (Fig. 9).

Design Tools Demonstrations and In-Class Practice

The second iteration involved weekly demonstrations of computer-based (e.g., PowerPoint, Publisher, Audacity) and analog (e.g., Sketching, Storyboarding) design tools. Such demonstrations included show-and-explain and step-by-step instructions. We also added additional resources in the form of handouts and video tutorials. These additional resources were provided on the Canvas course site (Fig. 10).

Additionally, the second iteration involved allocating class time to work on projects in the form of *studio days*. On studio days, students worked on their projects, practiced design tools, and experimented with different production paths while being supported by the instructor. Students received prompt feedback and peer reviews that allowed them to iterate on their design and practice using their design tools. We recognize the importance of studio pedagogy in design (Hokanson & Gibbons, 2013), and we wish we had the opportunity to turn this class into a studio format entirely. However, institutional constraints prevented us from doing so. Some of these constraints included a lack of learning space, lack of ability to change the course structure through administrative processes, and the significant time investment that it would require.

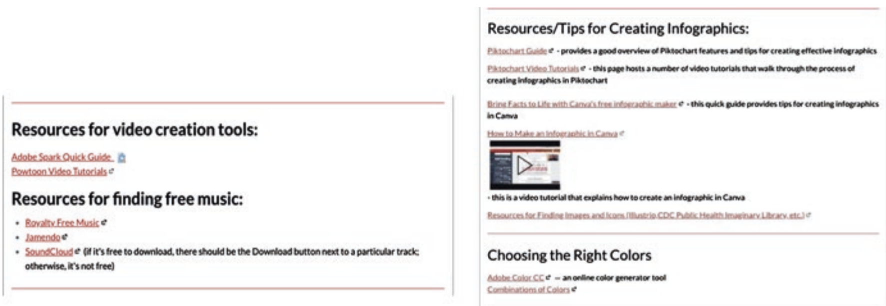


Fig. 10 Examples of Canvas course pages with a list of additional resources for creating infographics and producing videos

Why Authenticity of Assignment/In-Class Activities, Design References/Exemplars, and Design Tools Demonstration/Practice?

We think that training students in the context of their future professional context constitutes a pedagogically sound approach. When designing authentic tasks, we were guided by the description of authentic learning offered by Brown, Collins, and Duguid (1989). Particularly, per Brown et al. (1989), authentic learning situates newly acquired knowledge in the context of future use, since context and learning are inseparable. Further, we considered the four characteristics of authentic learning that Shaffer and Resnick (1999) put forth, namely, that authentic learning can be regarded as (1) learning that is personally meaningful, (2) learning that is connected to the outside world, (3) learning that mimics or models disciplinary practices, or (4) learning in which assessment is aligned with learning tasks.

During the second iteration of the course, we had a feeling of being on the right track and doing something right. We anticipated increased student engagement and enthusiasm regarding the course, as students could relate to these topics. At the same time, one of the challenges was making sure to use appropriate terminology for the context of public health and to make this terminology consistent with other public health courses that students took. Our purpose in doing so was to minimize the confusion among students that could occur as a result of using a multitude of terms.

Additionally, the rationale for emphasizing design references/exemplars is our familiarity with design theory. Design references/exemplars allow students to form design precedents, which are essential tools in design (Boling & Smith, 2008). These design precedents can help students find ideas (i.e., inspiration) and refine their artifacts (i.e., iteration). Additionally, we found that using design references/exemplars as the foci of class discussions allowed students to form their own design judgments and identify the values and biases that they might have.

As for design tools, we recognized that the concept of design tools did not encompass only actual/tangible types of tools; it included methods, techniques, and approaches to design (Lachheb & Boling, 2018). This open-ended approach to design tools allowed us to help students form and evoke their own judgments in selecting and adopting design tools (Boling & Gray, 2015). We think that practicing design tools and experimenting with different production paths during in-class studio days is beneficial for students who are learning design skills. We believe in studio pedagogy because it provides a space where students can get immediate help. This approach also allows for time to check on students' progress on their projects, helping to prevent students from getting lost.

Conclusion

In this design case, we described the design of an interdisciplinary undergraduate course—R341, Multimedia in Instructional Technology—that teaches multimedia design and production skills to undergraduate students majoring in public health. Throughout two iterations of the course, we made design decisions by relying on our design judgments, our design knowledge, and experience. We aimed to help students develop strong multimedia design and production skills that were relevant to the field of public health, because the abilities described earlier are aligned with core competencies essential in the workplaces of public health professionals. Our focus on the development of design skills allowed us to contextualize the course within the students' public health majors and in their future professional practice. This allowed the course to become interdisciplinary, in which public health and instructional design—two non-neighboring fields—met.

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Interdisciplinary Learner Engagement: Bridging Corporate Training and K-12 Education

Scott Gibbons and Kay K. Seo

Introduction

This chapter explores learner engagement strategies used by corporate trainers and K-12 educators in order to reveal which engagement strategies can be adjusted and used in different ways to benefit learners from both realms (corporate training and K-12 education). Additionally, this chapter provides reasons for interdisciplinary sharing of engagement strategies between K-12 educators and corporate trainers. This study is framed as a conceptual examination of learner engagement strategies discussed in the literature involving both corporate training schemes and K-12 teaching strategies. The findings are then compared with qualitative interview data collected from current K-12 educators and corporate learning and education department members from corporate America. The two guiding questions for this study are: (1) Which engagement strategies are common strategies for corporate trainers and K-12 educators? (2) How can engagement strategies be adapted for use across disciplines? A review of the literature surrounding K-12 education and corporate training engagement strategies helped to establish common themes and common language between the two worlds. A clear line began to emerge between how corporations use learner engagement strategies and how K-12 educators use learner engagement strategies, but many similarities also came to the forefront. The overlap of engagement strategies and their distinct uses in corporate training and K-12 education revealed an interesting trend.

Educational researchers define learner engagement in different ways, but this study uses Kuh's (2001) definition to structure and organize the findings: "Engagement refers to the time and effort that learners invest in studies and other activities that lead to student success" (Heaslip, Donovan, & Cullen, 2014, p. 12).

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Along with the definition of engagement, the study uses a set of three components (behavioral, cognitive, and emotional) to create a model of learner engagement (Ding, Kim, & Orey, 2017; Gallagher, Bennett, Keen, & Muspratt, 2017). According to Gallagher et al. (2017), the *behavioral* component reflects learners' participation and effort; the *cognitive* component focuses on learners' enthusiasm, interest, and attitude; and the *emotional* component pushes students to form their own goals and strive to achieve them. These three components were used to categorize the engagement strategies used by the reviewed research and study participants.

Corporate training takes place within companies for a variety of reasons and with a variety of employees, from upper management to low-level, part-time workers. For the purpose of this study, the term *corporate training* maintains the definition put forth by Masalimova, Usak, and Shaidullina (2016), suggesting that an employee's "knowledge and skills are…insufficient to work successfully in the company" (p. 1480), which requires a company to invest resources to train those employees in order to further develop their skills so that they can work successfully within the company. Hence, the focus of corporate training in this chapter adheres to larger companies that have a learning and development team typically made up of human resource representatives with education backgrounds and instructional designers with corporate training experience.

In addition to corporate trainers participating in this study, K-12 educators were selected to represent a different realm of education because the hypothesis for this study was that corporate trainers and K-12 educators would not use similar learner engagement strategies because they do not share the same population, and they are educating their population for different reasons. However, findings suggest that K-12 teachers and corporate trainers use many similar strategies to engage learners. Thus, corporate trainers and K-12 educators can share learner engagement strategies and learn from one another. Although no specific content area or type of corporation was targeted for this study, later research may demonstrate that certain K-12 content areas have more in common with certain corporate training agendas, which can translate into a stronger interdisciplinary study with a narrower focus.

Frame of the Inquiry

This study is an inquiry into learner engagement strategies from both corporate training and K-12 education based on semi-structured interviews (DiCicco-Bloom & Crabtree, 2006), web searches (Lindgren, 2018), and an extensive literature review. Because the study is framed as an inquiry, interview data was collected from a small population of participants, and the information was then processed to compare with findings from an in-depth textual analysis of available literature and to triangulate key engagement strategies and explain how those engagement strategies inform both K-12 education and corporate training.

Participants for this study consisted of three K-12 teachers and two corporate trainers. Teacher participant #1 is a secondary history teacher at a suburban high school in the Midwestern United States. Teacher participant #2 is an engineering teacher at a rural high school in the Midwestern United States. The third participant, teacher participant #3, is an elementary teacher at a rural school in the Midwestern United States. These teachers were selected from a small pool of teachers who responded to an email inquiry about using learner engagement strategies in their classroom. The fourth participant, corporate trainer #1, is the founder of an online learning agency that works with companies in order to develop trainings and training programs for those companies. The fifth participant, corporate trainer #2, works as a learning and development manager at a marketing firm in the Midwestern United States.

Participants responded to a series of semi-structured interview questions aimed at exploring how those participants used different strategies to engage learners. Questions were in part derived from an expansive literature review. Follow-up questions were based on participants' initial responses. Some interview questions were quite broad: "What are some engagement strategies you use with your learners? Why do you think it is important to engage learners in content and/or your learning objectives? How do you decide which strategies to use?" Other questions were more direct: "How do you use storytelling as a teaching method with your learners? What are some ways you have adapted a role-playing strategy to develop learners' content-related skills?" Interview data was transcribed and uploaded to the Dedoose qualitative analysis program and then analyzed for common themes such as learner engagement strategies, technology tools, overlaps between corporate training and K-12 education, and objectives for engagement strategies.

Learning Objectives

Even though the audience, situation, and applications can be very different, learning objectives for both corporate and K-12 education remain consistent. According to Byrne, Delmar, Fayolle, and Lamine (2016), objectives in corporate training are skills based, just as are the objectives in K-12 education (Jung, 2016). In K-12 education, even in the age of standardized testing, many teachers are moving from the idea that students are empty vessels in which a teacher deposits knowledge—as researchers such as Rodriguez (2012) contend. Teachers like participant #2 have realized the importance of engagement strategies that help students achieve learning objectives. Teacher participant #2 states, "When students are doing rather than just listening and taking notes, they retain the content better. Students become invested in their own learning and start to take ownership. Rather than just waiting for the teacher to tell them what they need to know" (personal communication, May 23, 2019). Teacher participant #1 echoes teacher participant #2's sentiment toward students engaging with learning objectives. Teacher participant #1 states:

> There is no one that appreciates being lectured for hours on end, so engaging learners in various instructional tasks and objectives allows for a wider range of possible classroom activities, but more importantly, a wider range of assessment possibilities to measure

> learning in a variety of ways to meet the needs of a group of diverse learners. (personal communication, May 30, 2019)

One way that corporate trainers and K-12 educators align on the importance of learner engagement is by paying close attention to learning objectives and how strategies can be designed to meet those objectives.

Objectives serve multiple purposes within both the corporate and academic worlds. Ross (2014) refers to learning objectives as strategic goals and explains that assessing a business's needs in order to develop those strategic goals can take different forms. In their cooperation with a large restaurant chain, Chan, Millier, and Monroe (2009) used the ADDIE model to develop objectives for an online training program they created in conjunction with outside consultants. Establishing the business's needs before developing objectives and then using those objectives to drive the curriculum reflects the way K-12 educators develop learning objectives to fit their curriculum and build toward standardized assessments. In academia, courses are structured around content and the established assessments, but some teachers develop objectives based on other criteria. For example, teacher participant #1 mentioned that he takes a variety of factors into consideration when developing learning objectives, including students' existing knowledge of historical concepts, difficulty of concepts, and the type of assessments that will be given. These factors are reflected by corporate trainer #1, the founder of an online learning agency, when she creates training courses for businesses. Even though technology is the vehicle by which corporate trainer #1 designs trainings, she suggests the importance of humanizing the curriculum by considering individuals' unique needs. Similarly, Ross (2014) acknowledges the relationship between the employee and employer when he states that career development can "strengthen an organization's core competency so that both the organization and the individual benefit over the long term" (p. 187). By expanding Ross' observation to corporate training, one could argue that corporate training should also benefit both the employer and the employee, and that, according to this study, learner engagement strategies are the means to accomplish that goal. The same can be said for K-12 education because teachers benefit when students are successful (Spilt, Hughes, Wu, & Kwok, 2012).

Corporate training and K-12 education share other important characteristics as well. According to corporate trainer #1, who worked as a secondary educator before corporate training, both corporate training and K-12 education are outcome oriented. Corporate trainer #1 indicates that both have goals that lead to a change in behavior, the creation of a product, or the creation of a strategy to solve problems. In many cases, the educational delivery system is the same between corporate training and K-12 education, such as an online discussion board; and the desired outcomes are the same, such as improved problem-solving skills, but the application of the skills may vary greatly. In the following sections, this chapter examines the impact context has on the various engagement strategies and the ways corporate training and K-12 education employ learner engagement strategies to benefit knowledge and skill acquisition.

Authentic Learning Environments

Authentic learning means that the skills required to solve a problem can be translated and applied to a real-world scenario. In the corporate world, an authentic learning environment may take the form of an existing office space where clients meet with employees in order to build relationships and discuss the client's needs and how the employee can meet those needs. In K-12 education, an authentic learning environment may be students working in collaborative groups in order to conduct an experiment that may mimic similar experiments they would be expected to conduct for certain careers in various fields. When discussing the importance of authentic learning, Westberg and Leppien (2018) state that authentic learning can "result in increased intrinsic motivation, growth in 21st century critical and creativity skills, and greater self-efficacy toward research and creative productivity" (p. 13).

Many researchers focus on skills-based practices when discussing authentic learning environments (Riddell, 2018) because building a learner's skills in different areas of study or business is the main objective for both K-12 educators and corporate trainers. Riddell approaches authentic learning environments in a unique way when teaching English language arts students. Riddell models her instruction after legal trials in order to teach students about literary concepts such as Shakespearean drama and literary analysis. Zwahlen (2017) uses authentic learning environments to promote student growth in elementary and high school science classes. In her study, Zwahlen discusses how kindergarten teachers had students collect rocks and plants, dissect the plants, and then "interweave" vocabulary with each specimen to teach both science and language acquisition (p. 88). Similarly, corporate trainers can use authentic learning environments to help employees learn the skills necessary to occupy critical roles within a company (Oh & Solomon, 2014). When designing a role-play protocol, Oh and Solomon intentionally immerse employees in a realistic, authentic environment to maximize employee-skill development. Both K-12 educators and corporate trainers can benefit from maintaining an authentic learning environment when preparing leaners for skill development.

Overlapping Engagement Strategies

The type of engagement strategy used also depends on the type of knowledge necessary to achieve certain tasks. Corporations engage learners by focusing on tacit knowledge, while K-12 educators focus on both tacit and explicit knowledge (Byrne et al., 2016). One factor that many corporate training strategies have in common is that they engage employees in the specified curriculum by immersing the employees in practical scenarios that allow the employees to promptly apply the training experiences to better navigate real-life work events. Masalimova et al. (2016) highlight many such training strategies when discussing international corporate training techniques. K-12 educators can use corporate training strategies to engage younger learners in content-specific material. The following sections highlight the most engaging strategies used by corporate trainers and K-12 educators as indicated by interview participants, web searches, and the literature regarding the topic.

From Corporate Training to K-12 Instruction

This section focuses on corporate training methods that engage learners in the content and the skills-acquisition process. Each method is discussed in terms of how corporate trainers use the method and how K-12 educators can adapt and use the same method to engage their students in the learning process.

Case Studies

The use of case studies as a method to train employees is an interactive way to engage employees in the training process. Case studies "involve an up-close, in-depth, and detailed examination of a subject, as well as its related contextual conditions" (Masalimova et al., 2016, p. 1482). Employees experience a real-world situation and sometimes even venture off campus to engage with other experts. Often employees work together to solve problems and to examine a particular case with in-depth analysis. In his study of 200 corporate trainers, Gundars Kaupins (1997) found that case studies were best used for "changing attitudes, improving interpersonal skills, and cultivating problem-solving skills" (p. 5). He also found that trainers were more involved when using case studies as a training method than they were when using other training methods such as lecturing or presenting.

In addition to case studies being an effective corporate training tool, K-12 education can benefit from using case studies to improve students' problem-solving skills and critical thinking skills. One of the main aspects of case study as a teaching tool is to create an authentic environment where learners can work together to solve problems and enhance relevant skills. Teacher participant #2 explained that she found it effective to have her engineering students work together to solve problems and "develop solutions" (personal communication, May 23, 2019). K-12 teachers can even take students out of the building to engage in cases such as a history class going to a museum to use artifacts to solve a historical problem that early Americans faced. An English language arts teacher can take students to a canonical author's home to learn about the writer's history and then analyze that author's writing from a biographical perspective.

Role Playing

Using role playing as a training method engages employees in the learning process so that they are able to gain a better understanding, through experience, of the areas where they need improvement. According to Oh and Solomon (2014)**:**

> Role-playing is a simulated interaction wherein designated participants assume—and to the best of their abilities, embody—specific roles in an imaginary situation and behave to fulfill a set of learning objectives, allowing participants to experience feelings, practice skills, and gain insight within the safety of a controlled exercise. (p. 216)

Kaupins (1997) found that role playing improved a variety of skills, not just work-related skills such as customer relations or retail sales tactics. Corporate trainer #2 uses role playing to help employees practice "real" conversations they "will need to deliver, versus generic scenarios" (personal communication, Sept. 12, 2019). Masalimova et al. (2016) also indicate the many benefits of role playing as a training strategy, and they suggest that role playing "makes it possible to understand the motives of the behavior of one or another worker" (p. 1482). The engagement of learners with authentic learning environments with methods like role playing can have many benefits beyond specific corporate-skill development.

K-12 educators can use role playing as a way to engage learners in a variety of exercises in order to improve upon many different skills. In their study of using role playing in high school science classes to teach about climate change, Belova, Feierabend, and Eilks (2015) found that students were able to make personal connections to the science content because of the role-playing activities the teachers in the study used. Likewise, teacher participant #1 incorporates role-playing games into his history curriculum in order to engage students in real-world, historical scenarios that they otherwise would not have the opportunity to experience. Teacher participant #3 uses role playing with elementary students when reviewing reading questions. Similarly, Ma et al. (2016) had students create avatars when engaging in role-playing activities in a high school algebra class. Using role playing to engage learners in content and to develop necessary skills can be an effective way to immerse learners in an authentic learning environment while still maintaining the feeling of being safe in an educational setting.

Storytelling

Storytelling in corporate training requires learners to share stories about "the lives of peers and colleagues [in order to] to present information about traditions, philosophy, and corporate culture" (Masalimova et al., 2016, p. 1483). There are different ways to use storytelling in corporate training. Digital storytelling (Hack, Ramos, Pinto, & Freitas, 2015) requires learners to interact with each other remotely, through online learning management systems such as StoryLearn (Hack et al., 2015), to evoke emotional connections to content and skills. Another form of storytelling is for learners to tell stories in-person about their experiences so that there is direct engagement with other learners who can then sympathize with the sharer's experience. Corporate trainer #2 uses storytelling in small groups with visuals like flipcharts to engage employees in the training process. From these storytelling activities, learners are engaged in company practices and can better navigate the pros and cons associated with certain aspects of the company, which can later lead to the corporate trainer pinpointing certain skills that need to be acquired or existing skills that need to be enhanced.

Storytelling as a teaching method for K-12 educators can connect students to the material they are learning in new and exciting ways. Mercat, Filho, and El-Demerdash (2017) use storytelling to help K-12 students think more creatively when solving math problems. Mercat, Filho, and El-Demerdash suggest that when using storytelling as an instructional strategy, it is important to make activities interactive in order to stimulate creative thinking in students. Teacher participant #1 uses storytelling with his history students to help them find commonalities among their understanding of certain historical concepts. Teacher participant #2 uses storytelling with her engineering students to help them think more creatively about how to address structural decisions when they are designing layouts for houses in a digital drafting program. Using storytelling as an instructional method to engage learners in creative ways to connect new skills to existing skills can pave a path toward self-discovery and intrinsic motivation.

From K-12 Instruction to Corporate Training

K-12 educators employ many of the same strategies mentioned by Masalimova et al. (2016) and corporate trainer #1 regarding corporate training. Herrington, Oliver, and Reeves (2003) discuss the importance of authentic learning environments and using strategies that help students make connections to real-world applications, which Herrington, Oliver, and Reeves call "the suspension of disbelief" (p. 60). Teacher participant #1 and teacher participant #2 also use real-world engagement strategies with their students. Authentic learning strategies used by K-12 educators can be used by corporate trainers to engage learners in content and skill development.

Project-Based Learning

According to Lee, Huh, and Reigeluth (2015), project-based learning is "an innovative approach to engage students in an authentic project or problem, to allow students to drive their own learning through inquiry and to work collaboratively on projects" (p. 562). Lee, Huh, and Reigeluth also suggest that project-based learning has other benefits such as the development of learners' social skills and enhancing group dynamics. Teacher participant #3 has elementary students work collaboratively with text features, which helps struggling students gain important foundational knowledge through interactions with peers. Teacher participant #2 discusses her use of project-based learning with her engineering students when she states, "Students are able to discuss with each other their ideas and possible ways to solve a problem. It builds a better community and students start to feel more comfortable not only asking each other questions but also asking the teacher" (personal communication, May 23, 2019).

In corporate training, corporate trainer #1 promotes project-based learning and peer interactions when training employees through their corporate training company. Corporate trainer #1 says that live coaching is an important aspect of remote and in-person training because learners require feedback in order to reinforce the vision put forth by the business. Each of the strategies mentioned by corporate trainer #1 involves the development of key skills by requiring trainees to use those skills in simulated scenarios. Corporate trainers can use project-based learning to immerse employees in a relevant venture to solve problems often related to a work-related project. The development of key problem-solving skills is often highlighted in project-based learning (Young & Legister, 2018), causing trainers to design projects that focus on a company's objectives so that the project is not only related to authentic scenarios but also requires authentic skills in order to successfully navigate the problem and solve it.

Cooperative Learning

K-12 educators use cooperative learning in different ways to group students and to help students learn from each other (Kagan & Kagan, 2009). In cooperative learning environments, learners work together to solve a problem and each group member has a specific role—either assigned by an instructor, or the learner assumes that role through a needs assessment conducted by the group. Teacher participant #2 mentions the importance of cooperative learning strategies that require her engineering students to work together to develop a solution to a problem. Teacher participant #1 takes a different approach from teacher participant #2 by using more direct engagement strategies with his history students, such as textual analysis and artistic representations of concepts. Teacher participant #1 still requires students to work in a cooperative group environment in order to utilize key skills outlined by his social studies learning objectives.

Corporate trainers can use cooperative learning strategies to engage employees in skill development. Corporate trainer #2 uses peer coaching circles with case studies for employees to simulate real scenarios and solve provided problems while being guided by a corporate trainer. Because many corporate trainers highlight authentic learning as an important aspect of training, cooperative learning can offer trainers a group environment where different employees are required to assume different roles in order to address a company's need, which can reflect the types of situations that employees may encounter on a daily basis.

Using Technology to Promote Learner Engagement

The previous sections of this chapter focused on traditional learner engagement strategies, but many corporate trainers and K-12 educators are adapting traditional strategies to online platforms. Although traditional corporate trainers rely heavily on face-to-face communication when training employees, many companies are moving to e-learning platforms in order to save time and money when training employees (Kimiloglu, Ozturan, & Kutlu, 2017). Dodson, Kitburi, and Berge (2015) discuss the many possibilities that massive open online courses (MOOCs) offer corporations when training and enhancing the skills of employees. Entire business models are now dedicated to the idea of using technology to engage learners using different strategies from ones listed by Masalimova et al. (2016) but building on the same skills that those strategies emphasize. The company Designing Digitally describes their agenda by stating, "We engage your learners, increase their knowledge retention, and inspire success with fully-customized web-based training" (Designing Digitally, 2019, para. 1). Edmaker (2019) makes a similar commitment to clients by stating, "We create the perfect mix of features that works for your audience or team" (para. 1). Companies such as Designing Digitally and Edmaker focus on similar outcomes outlined by Kimiloglu et al. (2017). They found that technology-enriched engagement strategies can increase employee interest, morale, and motivation. Engagement strategies can also build cooperation among employees and create a less-stressful learning environment by focusing on interactivity and pacing (Kimiloglu et al., 2017).

Like corporate trainers, K-12 educators implement a variety of technologies to build student engagement such as online discussions (Ding et al., 2017), flipped classrooms (J. Lee, Park, & Davis, 2018), student-response systems (Heaslip et al., 2014), MOOCs (Kerrison, Son, Grainger, & Tutty, 2016), and gaming (Zheng & Spires, 2014). Researchers found that K-12 educators use technology-rich engagement strategies to build and enhance students' skills in a similar fashion to the way corporate trainers build and enhance employees' skills through challenging activities, active and collaborative learning, and promoting a positive learning environment (Heaslip et al., 2014). Herrington et al. (2003) state, "The use of authentic activities within online learning environments has been shown to have many benefits for learners in online units and courses" (p. 59). Authentic learning in education, according to Herrington, Oliver, and Reeves, means that there are real-world applications to tasks, collaborative exercises, occasions to reflect, and opportunities to work toward a finished product. Likewise, in reference to corporate engagement strategies, Byrne et al. (2016) state, "The nature of action learning requires that individuals have the time to interact with others, engage in action and reflect on their learning" (p. 501).

The important role technology plays in learner engagement is becoming an important way to educate all types of learners. Edmaker develops online training programs for companies; Chan et al. (2009) developed a college course around building affordable training programs for companies; and Hack et al. (2015) conducted research on digital storytelling as an effective way to connect trainings to employee's personal needs. Teacher participant #2 incorporates coding and programming into her engineering course to give students hands-on experience when working with software and robotics. Teacher participant #1 uses online discussion boards and webquests to promote learner engagement with his history students, and both teacher participant #1 and teacher participant #2 use online tools such as

Kahoot, Quizlet, and Quizizz to formatively assess students' ability to retain knowledge. Corporate trainer #1 uses polling software to assess corporate employees in order to determine the effectiveness of the training and areas where she needs to make modifications to her training programs.

Conclusion

The overlap between corporate engagement strategies and K-12 engagement strategies shows that similar strategies can be used for different purposes in order to elicit similar outcomes. Based on the findings, this study suggests that corporate trainers and K-12 educators can learn from each other when using different methods to engage learners. Successful engagement strategies in K-12 education can prove to be just as effective in the corporate world and vice versa. A space should be made available where corporate trainers and K-12 educators can share engagement strategies and discuss their approaches to engaging learners in new and effective ways. By making connections between these two worlds, corporate trainers and K-12 educators can enhance the way they develop teaching strategies to promote learner engagement and learner success.

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