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Bringing User Experience Design to Bear on STEM Education: A Narrative Literature Review

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Abstract

This narrative review addresses emerging application of user experience (UX) design principles within education contexts, particularly science, technology, engineering, and mathematics (STEM) education settings. In this review, "UX design" is employed as an umbrella term to describe design philosophies, approaches, and tools that have originated within technology product design-related fields, namely user-centered design and human-computer interaction. UX design implies commitment to user-focused approaches to product development; UX design commonly includes construction and use of specific design tools (e.g., personas, scenarios, and usage models) that synthesize and contextualize product users' goals, needs, wants, and behaviors in memorable and empathic ways. This review not only explores implementation of UX design tools and frameworks within education settings, but also examines the methods that have used to develop and implement UX design tools from data generated with students and faculty. Findings reveal that, although nascent, current scholarship provides evidence to support use of UX design tools and approaches to promote instructional innovation and the transfer of research to promote institutional change. To advance these purposes, STEM scholarship should focus on providing methodological detail and evidence of assessment of outcomes related to UX implementation. The results further suggest that future work in this area should explore novel approaches for representing UX design tools contextually within STEM settings.

Keywords Human-computer interaction · Persona · Research to practice · Scenario · Usage model · User-centered design

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Purpose

A common critique of educational research in general (Helmsley-Brown and Sharp 2003; Lagermann 1997; Reese 1999), and science, technology, engineering, and mathematics (STEM) educational research in particular (Beach et al. 2012; Borrego and Henderson 2014; Henderson et al. 2011), is the slow rate at which evidence-based strategies are adopted into administrative policy and teaching practice. In STEM education, these critiques are heightened by increasing calls, within the United States for example, for educators to innovate in their teaching in order to 1) improve instructional effectiveness amid decreasing student enrollment and retention rates and 2) increase the diversity and socio-technical mindedness of the twenty-first century science and engineering workforce (see e.g., National Academy of Engineering 2004; National Research Council (NRC) 2012; President's Council of Advisors on Science and Technology (PCAST) 2012).

In recent years, education scholars have started to explore how application of user experience (UX) design principles might assist the education community in meeting these challenges. In this review, we employ "UX design" as an umbrella term to describe those philosophies, approaches, tools, and techniques, originating within fields such as user-centered design (UCD) and human-computer interaction (HCI), that are commonly employed in industry to make market and user research data accessible to and compelling for product designers. The purpose of this narrative review is to: (1) synthesize available scholarship related to the application of UX design principles within education, with a particular focus on STEM education settings, (2) identify methodological considerations for implementation of UX design approaches using data generated with students and/or faculty, and (3) provide recommendations for future scholarship in this area. This review can assist researchers and educators in making connections across disciplinary boundaries and developing plans to explore similar approaches for robustly linking educational research and practice.

Background on UX Design

Originating since the time "…when the potential for computer-based technologies was first being fully recognized," UCD and HCI are two fields that focus on ways to design technology-related products and systems expressly for human use (Ritter et al. 2014). Specifically, UCD is a design philosophy which envisions product design as a cyclical process that includes (1) general requirements analysis, (2) contextual task analysis, (3) system prototyping, (4) early evaluation, and (5) iterative design (Ritter et al. 2014). While the fields of UCD and HCI do overlap, HCI is largely focused on the study of the interaction of humans and computers well beyond the design of human/computer interfaces. Now a core area of post-secondary computer science curricula (Ritter et al. 2014), HCI remains rooted in the social sciences, namely distributed cognition, phenomenology, and activity theory (Kaptelinin 2013). Today, HCI considers as its purview the movement of computers out of the workplace and into everyday private and public life, including the emotional, aesthetic, pragmatic, and socio-cultural aspects of human–computer experience (Ritter et al. 2014).

UX Design Tools

During the past few decades, UX design approaches have received widespread attention for their utility in communicating complex, contextualized information about product users in memorable, empathic, and evocative ways (Rosson and Carroll 2002; Norman 2004). The two most common UX design tools, *personas* and *scenarios*, gained popularity within the fields of UCD and HCI, respectively, during the mid to late 1990s. Personas are fictional, "hypothetical [user] archetypes" constructed from purposeful research about real or potential product users (Cooper 2004). Unlike simple descriptions of real people, personas communicate the goals, values, needs, and actions embedded within targeted user groups and, thereby, help designers develop empathy and interest for a variety of users and user contexts during early stage design.

Personas are further categorized as data-driven or ad-hoc. Data-driven personas are constructed from research data to depict or embody the needs/values/goals and observed actions of current and/or potential users. Ad-hoc—or "fiction based" (Nielson 2013)—personas are constructed solely from personal assumptions and "embedded knowledge" about the traits and actions of product users (Cooper 2004; Adlin and Pruitt 2010). Ad-hoc personas are usually constructed early in a design cycle to expose designer bias, to create empathy for product users, or to motivate expensive data collection for data-driven persona development (Adlin and Pruitt 2010; Cooper 2004; Norman 2004). Since ad-hoc persona development is more effective at uncovering existing assumptions about users than at challenging or changing these preconceptions, it is common to move beyond ad-hoc personas to create data-driven persona during design (Adlin and Pruitt 2010).

Scenarios are narrative depictions (i.e., stories) of common but meaningful user activities that help designers define specific product features that reflect a user focus (Carroll 1999). Scenarios make "envisioned possibilities more concrete" (Rosson and Carroll 2002) by depicting product use explicitly. Rosson and Carroll (2002) suggest that scenarios can be constructed quickly; scenarios merely require setting, one or more actors with specific goals or objectives, plot, and outcome. Ease of construction has helped make scenarios a popular way to "[rapidly communicate] usage possibilities and concerns among many different stakeholders" (Carroll 1999). Forward-looking product scenarios are used to describe potential future actions users can take and, therefore, do not hinge on access to user data; available data can be used to build scenarios depicting current user actions to brainstorm new features/functions that are compatible with, or improve, user workflow (U.S. Department of Health and Human Services 2006). Another common UX tool, product *use cases,* are step by step descriptions of the product's required interactions with the user in order to accomplish a specific user task (U.S. Department of Health and Human Services 2006). Use cases are commonly developed directly from scenarios (Vorvoreanu et al. 2016).

Although persona- and scenario-based design approaches evolved separately, scholars point to inherent benefits of combining personas *with* scenarios. According to Pruitt and Grudin (2003), "scenarios are a natural element of Persona-based design and development." Adlin and Pruitt (2010) argue that traditional scenarios are more compelling when written in conjunction with personas, since personas contain important social and cultural information that help communicate the impact of contextualized usage details and proposed design features. Putnam (2010) suggests that scenarios that

are written with personas as actors are more effective at "helping designers keep users in mind"—a key tenant of UCD—than traditional scenarios written around generic users. Nielsen (2003) describes how normally "static" personas become "dynamic when inserted into the actions of the scenario"; scenarios bring personas to life by giving them a context, situation, and goal.

UX Usage Models

Along with simply combining individual design tools to enhance or support the benefits of the primary tool (e.g., adding scenarios to improve personas), product development teams may choose to integrate multiple design tools into detailed models of product usage. Historically, the term "usage model" is thought to have originated at Intel Corporation during the early 1980s; the term is derived from use cases that are commonly employed in computer engineering and software product development (Simmons 2006). Based on a desire to provide a "common structure and taxonomy for describing product usage to unify requirements engineering, planning, and design processes…; to promote reuse; and to communicate clearly with various stakeholders in myriad roles," Intel continued to develop conceptualizations of usage models during the 1980s and 1990s (Simmons 2006). Most recently, Intel documented a flexible, tiered usage model framework that allows design and development teams to synthesize individual UX design tools to depict (1) *supporting or background data* (e.g., personas, demographics, use conditions, ethnographic data), (2) *overview data* (e.g., roadmaps, storyboard, concept and context diagrams, user experience landing zones), and (3) *usage details* (e.g., use cases, scenarios, user task flows, operational profiles) in unique, context-dependent combinations (Simmons 2006). By combining tools across these tiers, Intel's usage model framework enables disparate groups within the company (e.g., design, production, and marketing groups) to focus on a common set of users throughout the life cycle of a product.

Research Questions

This narrative literature review was guided by the following three research questions:

1. For what purposes has UX design been employed within STEM education contexts? Within broader education contexts?
2. What methods have been used to construct UX design tools within education contexts?
    a. What methodological considerations, if any, arise from constructing UX design tools from data generated with students and/or faculty?
3. How have individual UX design tools been combined and/or synthesized into contextualized models within education contexts?

Methodology

Narrative literature reviews can be "irreplaceable" for tracing the origins and historical development of new ideas and concepts, especially those that sprout rapidly and with

little regard to disciplinary boundaries (Collins and Fauser 2005). Indeed, some review topics are better served by the more "comprehensive coverage" (Collins and Fauser 2005) and "wider scoping" (Ferrari 2015) characteristic of narrative reviews; in many cases the narrow focus and prescribed methods of systematic style reviews do not allow for broad investigation of nascent and/or interdisciplinary topics (Collins and Fauser 2005). This study was a narrative review related to the application of human-focused design (i.e., UCD and HCI) principles within higher education settings, with particular focus placed on the context of STEM education. Specifically, this narrative review took the form of a "narrative overview" in order to present a "broad perspective" on an emergent, educational topic by "pull[ing] many pieces of information together into a readable [narrative] format" (Green et al. 2006). The nascent and interdisciplinary nature of the review topic, along with the descriptive, non-experimental, and methodologically diverse set of current literature on the topic, led us to select the narrative overview as the appropriate methodology for this study. However, in order to reduce researcher bias and conduct the narrative review as objectively as possible, we adopted several methods (i.e., the formation of research questions and the use of inclusion and exclusion criteria) that are more characteristic of systematic reviews as recommended by several scholars (Ferrari 2015; Collins and Fauser 2005; Green et al. 2006).

Methods

First, we conducted preliminary searches using several databases, including SCOPUS, ERIC, and Google Scholar, to identify and establish the literature. These initial searches enabled us to define the scope of the published literature on the review topic and to refine the topic and research questions to be addressed in this review. After conducting preliminary searches, we adopted four inclusion and exclusion criteria to guide the literature selection:

1. The work is a peer reviewed article or published conference proceeding;
2. The work is available in full text;
3. The work is published in English;
4. The work describes application of UX design principles within

    a. STEM higher education
    b. General higher education

We agreed that studies that did not meet any one of the inclusion criteria would be excluded from the review. No date restriction was placed on the search so that the history and "narrative thread" of the topic could be preserved (Collins and Fauser 2005). We began our search in September of 2016 and stopped searching in May of 2018. The decision to include only full-text studies reflected the researchers' desire to read sources (not just abstracts) in their entirety in order to improve accuracy of the analysis and reporting; the decision to include only works published in English reflected the language skills of the researchers. In order to broaden the range of studies available for review, we extended search criteria, inclusion and exclusion criteria, and research questions to include application of UX design principles within general (i.e., non-STEM) education contexts.

After completing database searches, we conducted follow on searches to locate additional sources. To do this, we searched reference lists provided within the identified primary sources to (1) identify any primary sources that were not archived in the electronic reference databases we searched and (2) examine the methods-based resources that were referenced by the primary sources in order to gain a deeper understanding of the methodological processes for UX design discussed within the primary sources. In total, this review included 20 primary sources (eight studies conducted in STEM settings, 12 studies conducted in non-STEM and/or general education settings) and 22 secondary sources. A complete list of all literature (primary and secondary sources) included in the review is provided in the Appendix.

Limitations

Our study is limited for at least two reasons. The primary limitation of this review is source selection bias: researcher subjectivity in choosing articles to include in the review, is a common limitation of narrative style literature reviews (Ferrari 2015). We worked to mitigate this limitation by clearly defining research questions and inclusion and exclusion criteria for the study. The second limitation, which is common among all literature reviews as forms of "secondary research," is reliance on "best available evidence" for making claims (Ferrari 2015). For example, we encountered primary sources that did not adequately describe the methods used to develop and/or employ UX design tools during the study. We worked to mitigate this limitation by accessing secondary sources referenced within the primary sources to help us develop deeper understandings of the methods used prior to analyzing and reporting results of the review.

Results and Discussion

In the sections that follow, we first present the overall trends present within the UX education literature, followed by findings related to each of the three research questions.

General Trends within the Literature

The following discussion of general trends within the literature provides a description of the publication timeline and publication venues.

Publication Timeline The publication timeline of primary and secondary sources identified in this review is shown in Fig. 1. Primary sources ($n = 20$) included in this review were published between 1994 and 2018. Secondary (i.e., methods) sources ($n = 19$), which were identified within the primary source reference lists and used to gain insights into UX design methodologies, were published between 1997 and 2015.

UX scholarship set within general (i.e., non-STEM) education setting first appeared in 2006. While we identified a single article describing application of a UX design approach within elementary science education over two decades ago (Chandler 1994), UX scholarship within STEM education more fully emerged in 2011 (Fig. 1). Overall,

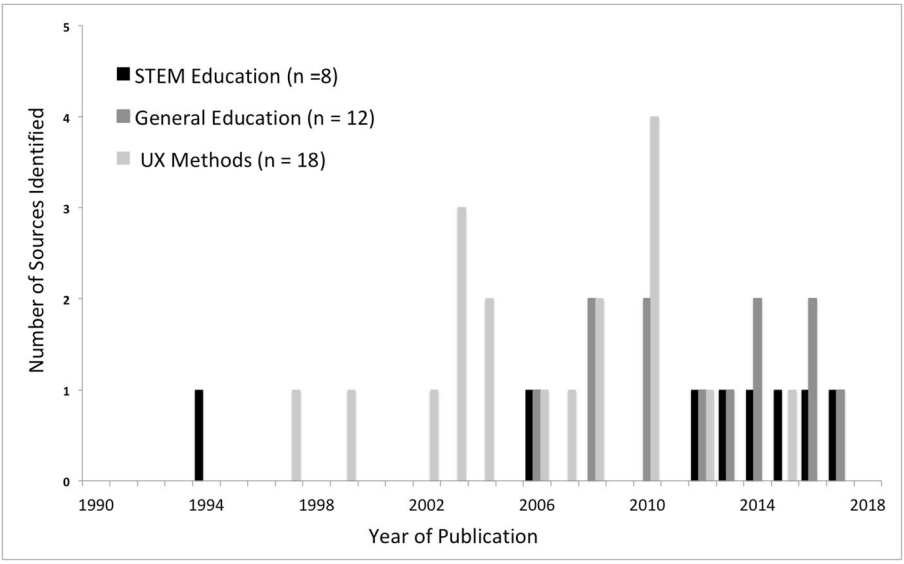

Fig. 1 Number and type of sources ($n = 42$) identified by publication year

results demonstrate a consistent interest in use of UX design principles within general education contexts since 2006, and a consistent interest within STEM education settings since 2011.

Publication Venues The primary sources ($n = 20$) included in this study (i.e., those describing application of UX design in STEM or general education settings) were comprised of 14 journal articles and six conference proceedings. Primary sources were published in a wide variety of journals and conference proceedings that each focused on one of six major topic areas: (1) general education; (2) human-computer, technology, or media interaction; (3) information and library science; (4) social and behavioral science; (5) engineering education; and (6) computer science education. Figure 2 depicts the number of primary sources included in each topic area.

Approximately one-third (7/20) of the primary studies were published in information and library science journals (e.g., *College & Research Libraries*, *Journal of Library & Information Services in Distance Learning*, *Performance Measurement and Metrics*, and *Qualitative and Quantitative Methods in Libraries*). The remaining primary studies were published in journals focused on specific STEM education disciplines (2/20) (e.g., *Innovations in Teaching and Learning in Information and Computer Science* and *Journal of Engineering Education*), general education (3/20) (e.g., *Journal of Academic Leadership*, *Journal of Effective Teaching,* and *Education and Economics*) and human-computer and/or technology interaction (2/20) (e.g., *Cognition, Technology & Work* and *Journal of Artificial Intelligence in Education*). Conference proceeding publications originated from conferences devoted to research in human-computer and/or media interaction (3/20), engineering education (2/20), and social and behavioral sciences (1/20).

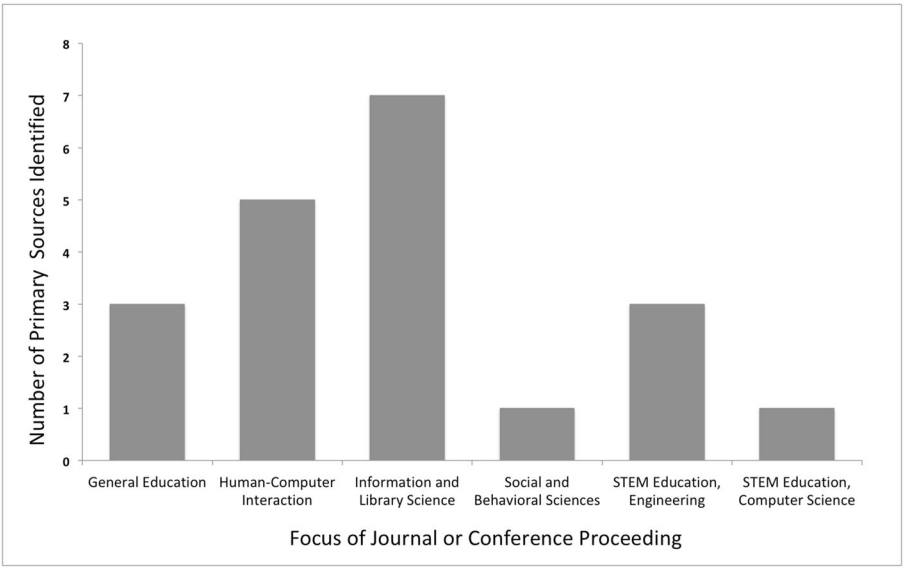

Fig. 2 Number primary sources ($n = 20$) by journal and/or conference proceeding topical area focus

Research Question One

To answer research question one, we examined primary sources to understand the reasons why UX design was implemented within STEM and general education settings.

STEM Education The review identified eight articles describing application of UX design in STEM education settings. As shown in Fig. 3, STEM education studies were

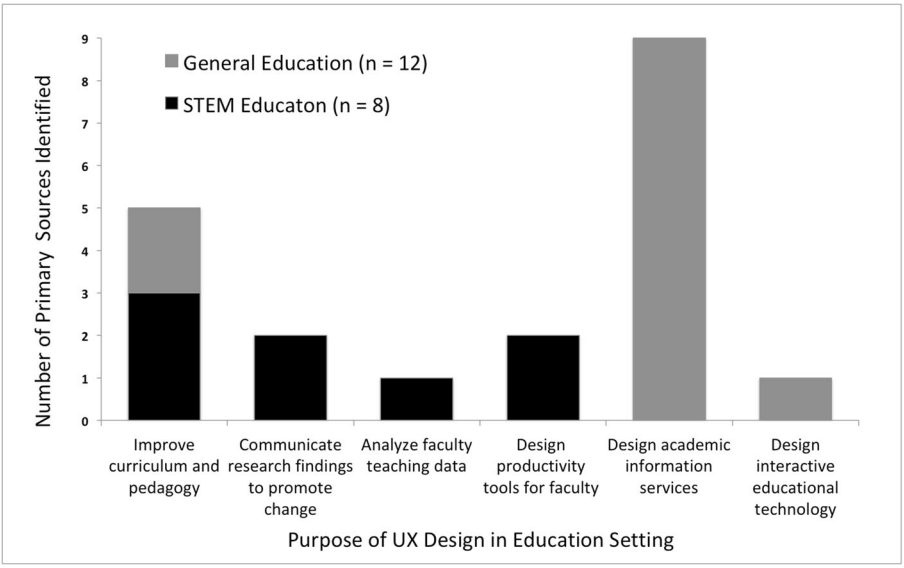

Fig. 3 Number primary sources ($n = 20$) by purpose for implementing UX design in an education setting

thematically grouped into four categories that depict the purposes for UX design tool implementation. Purposes include to (1) improve curricular design and pedagogy (n = 3), (2) communicate education research findings to higher administrative levels in order to promote institutional change (n = 2), (3) analyze research data related to faculty teaching behaviors, and (4) design research and general productivity tools for faculty (n = 2). A general explanation of each purpose is provided in Table 1.

Three studies (Turns et al. 2015; Lilley et al. 2012; Chandler 1994) implemented UX design *for the purposes of improving curricular design and/or pedagogy.* Chandler (1994) described a user-centered approach used to develop an artifical intelligence (AI) system able to provide pedagogical advice to elementary science teachers. The approach, which included construction of a user model, task model, and science teaching domain model, was found to facilitate achievement of design outcomes of the AI-based system. Lilley et al. (2012) constructed and applied student personas to assist in the development of online learning experiences for undergraduates enrolled in a distance computer science program. They reported that student personas were useful for uncovering and understanding key pedagogical (e.g., normative peer feedback) and technological (e.g., mobile device access) needs of the undergraduate learners in the distance-delivered program. They also noted that student personas helped to make the diversity that exists within their student population evident and visible to all curriculum stakeholders.

Turns et al. (2015) pointed to the "direct parallel" between user-focused product design and student-focused curricular design that motivated their exploration the application of personas within engineering education. The authors explain how, in each case, the goal of the design tools is to get research findings about users (students) into the "hands, heads, and design processes" of product (curriculum) designers as they engage in design and development activities (Turns et al. 2015). Specifically, they examined the effects of engaging several groups of engineering curriculum stakeholders, including engineering educators interested in leveraging personas; graduate students preparing to teach an undergraduate chemical engineering course; and incoming first year engineering students involved in a summer bridge program, in discussions

Table 1 STEM education purposes for UX and explanations

STEM education purpose for UX	Explanation
1. Improve curricular design and pedagogy	Provide results from data gathered among students to course/curriculum developers, faculty developers, and instructors to enable them to construct new or innovative learning activities, course-level policies, and instructional strategies to improve student outcomes
2. Communicate education research findings to promote institutional change	Provide results from data gathered among students and/or faculty to academic administration as evidence of the need for higher level educational policy change
3. To analyze research data related to faculty teaching behaviors	To synthesize and contextualize findings from data gathered about use of specific teaching strategies (e.g., active learning) among faculty
4. Design research and productivity tools for faculty	To analyze data gathered among faculty to inform the design of online database interfaces used by faculty

about teaching and learning using previously constructed engineering student personas as prompts. Their findings revealed personas to be flexible tools that are useful for prompting diverse audiences (i.e., faculty, graduate students, and undergraduates) to unpack biases and assumptions and reflect upon personal practices related to learning and teaching. The authors emphasized that persona construction takes substantial time and suggested that persona developers can benefit from a carefully considered methodological approach. They further noted that the time requirements for persona development could make a community-based approach to educational personas desirable.

Two studies (Finelli et al. 2014; Pawley 2013) described future application of faculty personas to facilitate communication with administrative STEM faculty leaders (e.g., department heads, associate deans, and deans) *for the purpose of promoting change at higher administrative levels*. Pawley (2013) described future plans for developing personas from narrative research data generated among members of student groups that are marginalized within engineering. She suggested that personas may help to effectively communicate research findings about institutional barriers faced by underrepresented minority engineering students to administrative leaders for the purposes of promoting policy change. Finelli et al. (2014) constructed personas to represent faculty stakeholders in an administrative change plan related to teaching in a college of engineering. The authors described future plans to construct a series of faculty personas that are able to illustrate the range of factors influencing faculty adoption of evidence-based teaching practices.

Guy (2017) constructed STEM faculty personas *for the purpose of analyzing research data related to STEM faculty use of active learning strategies* in order to gain a deeper understanding of STEM faculty perceptions about active learning teaching techniques and the barriers that STEM faculty face when implementing active learning within their courses. In the study, she constructed faculty personas using qualitative data generated with 12 multi-disciplinary faculty members who had teaching roles and used active learning strategies in their STEM courses. Findings from thematic analysis of qualitative data were used to construct four STEM faculty personas. Analysis of the personas suggested that (a) STEM faculty often require administrative help to overcome substantial barriers to adoption of active learning strategies and (b) while STEM faculty may share beliefs that active learning is as an effective pedagogical strategy, individual faculty are deterred from employing active learning strategies due to several factors, including physical classroom factors; human support factors (i.e., support from students, peers, and/or administration); activity preparation factors; and individual (i.e., creativity and/or fear) factors.

Two studies (Vorvoreanu et al. 2016; Vyas et al. 2006) described implementation of UX tools *for the purposes of designing web-based analytics and search tools for STEM faculty*. Vyas et al. (2006) developed personas from multi-method qualitative data in order to support web-based interface design for faculty in biology, chemistry and medical sciences. Vorvoreanu et al. (2016) used qualitative data generated with 24 STEM faculty members to develop personas, scenarios, use cases, and cognitive walk throughs for purposes of refining and evaluating the design of a web-based research analytics tool. The data addressed faculty members' daily schedules, sources of work satisfaction, goals, activities, needs, and challenges. The authors concluded that the persona method was useful for design refinement, including the creation of new features, as well as for evaluation activities conducted as part of the overall design

process for the web-based tool. They further noted that the personas themselves were important for highlighting the busy lives of STEM faculty and will be useful for future design efforts that expressly focus on this population.

General Education Our review identified 12 articles that described use of UX design tools in non-STEM or general educational settings. As shown in Fig. 3, general education studies were grouped into three categories describing the purposes for UX design implementation, including to (1) improve curricular design and pedagogy (n = 2), (2) design information retrieval and storage services (i.e., academic libraries and/or online repositories) (n = 9), and (3) design interactive educational technologies (n = 1). An explanation of each purpose is provided in Table 2.

Two studies (Kahraman 2010; van Rooij 2012) implemented UX design *for the purposes of improving curricular design and/or pedagogy*. In the context of three interior design elective courses, Kahraman (2010) concluded that their generalized user-centered design approach to curriculum development and teaching increased both course effectiveness and student success. van Rooij (2012) presented a technique for integrating empathy instruction into professional instructional design education curricula. Their technique required graduate students to construct personas, based on research data, of a selected audience; in this case, students constructed personas of parents of students with special needs. van Rooij (2012) concluded that persona-based curricular techniques were useful for teaching graduate instructional design students about empathy and offered further suggestions for adopting similar techniques in other, non-design related undergraduate courses.

By far, the largest group of primary general education studies (9/12) described implementation of UX tools to assist in the *design of information services, such as web-based retrieval and storage interfaces, for academic libraries and/or online repositories* (Koltay and Tancheva 2010; Lewis and Contrino 2016; Maness et al. 2008; Miaskiewicz et al. 2008; Sundt and Davis 2017; Tempelman-Kluit and Pearce 2014; Zaugg and Rackham 2016; Al-Shboul and Abrizah 2014; Volentine et al. 2013). Several authors (Al-Shboul and Abrizah 2014; Volentine et al. 2013) reported that personas were useful for gaining insight into the information seeking habits of

Table 2 General (non-STEM) education purposes for UX and explanations

General education purpose for UX	Explanation
1. Improve curricular design and pedagogy	Provide results from data gathered among students to course/curriculum developers, faculty developers, and instructors to enable them to construct new or innovative learning activities, course-level policies, and instructional strategies to improve student outcomes
2. Design information retrieval and storage services	Provide results from data gathered among students and/or faculty to inform the design of online repositories and library interfaces
3. Design interactive educational technologies	Provide results from data gathered among students to inform the design of formal and/or informal learning tools

successful faculty (e.g., humanities scholars and well-published early career faculty) and then using these insights to assess areas for improvement within current library systems. Other researchers (Sundt and Davis 2017; Lewis and Contrino 2016) found that use of personas helped library employees discern library users' actual needs and values from existing preferences and assumptions. Others reported how personas were useful as decision making tools when validating other (e.g., quantitative) user research findings (Koltay and Tancheva 2010) and making trade-off decisions (Zaugg and Rackham 2016). Still others (Zaugg and Rackham 2016; Sundt and Davis 2017) noted how personas helped focus library employees' conversations toward working together and improving services for patrons. Along with these positive outcomes, the time and/or expense associated with constructing personas manually was noted as a limitation to this approach by several authors (Lewis and Contrino 2016; Sundt and Davis 2017; Miaskiewicz et al. 2008; Maness et al. 2008).

Antle (2008) proposed and examined a detailed methodology for constructing "child personas" *for the purpose of designing interactive, educational technologies* for children. Antle (2008) described her technique as a new approach to persona construction since it is based not only on empirical data, but also on children's goals for experience and cognitive development theory. Antle (2008) reported that the technique might be also useful for designing for adults who rely on needs rather than work or productivity goals and noted that the technique was extremely enlightening for the designers themselves.

Research Question Two

To answer research question two, we examined both primary and secondary sources to understand the methods (i.e., data types and collection, data analysis, physical representation, and assessment) employed to develop and implement UX design tools within education settings.

UX Design Tools The majority (18/20) of primary studies included in this review reported use of data-driven personas; only two studies reported on the implementation of other UX design tools such as scenarios (Lilley et al. 2012; Vorvoreanu et al. 2016) and use cases (Vorvoreanu et al. 2016). Of those primary studies that implemented personas, only one study (Lilley et al. 2012) reported using both ad-hoc and data-driven personas.

Data and Data Collection Most (15/20) primary studies in this review described generation and use of qualitative data to develop UX tools. Several methods were used to generate qualitative data, including interviews (e.g., Lilley et al. 2012; Vorvoreanu et al. 2016; Zaugg and Rackham 2016), open-ended surveys (e.g., Lilley et al. 2012; Sundt and Davis 2017), focus groups (e.g., Finelli et al. 2014; Kahraman 2010; Zaugg and Rackham 2016), observations (e.g., Antle 2008; Finelli et al. 2014; Zaugg and Rackham 2016), chat or email transcripts (e.g., Lewis and Contrino 2016; Sundt and Davis 2017; Tempelman-Kluit and Pearce 2014), journaling or diary keeping (e.g., Vyas et al. 2006), and participatory group level assessment (e.g., Guy 2017). Within the broader methodological literature, it is noted that observational data collection methods (e.g., transcripts, direct observation, journaling) are particularly important to UX design

since more common data collection techniques, namely interviews and surveys, may not always directly address what users do (Goodwin 2002; Antle 2008; Tu et al. 2010).

Other primary studies (3/20) described (1) collection of mixed methods (i.e. qualitative and quantitative) data (Lewis and Contrino 2016; Volentine et al. 2013) or (2) collection and subsequent transformation of qualitative data into quantitative data for use in automated, statistical clustering algorithms (Tempelman-Kluit and Pearce 2014). Quantitative data was gathered from existing demographic data (Lewis and Contrino 2016) and survey responses (Volentine et al. 2013).

Data Analysis While ease of construction has helped popularize scenarios as UX design tools, persona construction remains an inductive, iterative process that continues to be researched and documented within a growing body of literature. Generally, persona developers seek to identify patterns of behavior, needs, and goals within user data, and then use these patterns to creatively construct fictional yet representative personas. Terms such as "qualitative clustering" (QC) (Adlin and Pruitt 2010; Brickey et al. 2012) and "qualitative coding" (Saldaña 2013) describe this general process of inductively grouping similar data.

A majority (12/20) of primary studies in this review reported using manual QC for developing personas. In practice, persona developers often participate in manual QC as teams via hands-on workshops. During these workshops, developer teams engage in card sorting exercises, known as "affinity diagramming" (Adlin and Pruitt 2010) or "The KJ Method" (Scupin 1997). Individually, developers use their experience and assumptions to generate and/or transfer user data (both quantitative and qualitative) to cards and then work collaboratively to group or "cluster" like behaviors, needs, and goals into descriptively labeled categories. They may choose to further segment some categories into subgroups. Developers use the groups and subgroups to form persona "skeletons" that become full personas as details are added (Adlin and Pruitt 2010). The authors of one primary study included in this review (Lewis and Contrino 2016) desribed the use of "empathy maps" as intermediate persona development step between data clustering and persona creation. As described by Ferreira et al. (2015), empathy maps help designers define the emotions motivations, needs, and fears of each persona from the data.

Critiques of "manual QC" include the (a) need for specialists to use expert judgment during clustering (Brickey et al. 2012), (b) perceived lack of developmental rigor, compounded by difficulty documenting how persona characteristics trace back to data (Adlin and Pruitt 2010; McGinn and Kotamraju 2008), and (c) time/expense of collecting qualitative data when quantitative data is available (Pruitt and Grudin 2003; Brickey et al. 2012). These critiques are leading persona developers to explore "semi-automated," statistical clustering approaches (Brickey et al. 2012);

Three studies in this review (Maness et al. 2008; Miaskiewicz et al. 2008; Tempelman-Kluit and Pearce 2014) employed emerging statisical clustering approaches. Statistical clustering approaches include Cluster Analysis (CA) (e.g., Tu et al. 2010; Tempelman-Kluit and Pearce 2014), Factor Analysis (FA)/Principal Component Analysis (PCA) (e.g., Sinha 2003; McGinn and Kotamraju 2008), and Latent Semantic Analysis (LSA) (e.g., Maness et al. 2008; Miaskiewicz et al. 2008). CA and FA/PCA are robust and capable of reducing large quantitative datasets. While CA reduces multivariate data domains by segmenting them into a predefined number of

clusters, FA/PCA reduce/combine data by identifying the underlying structure (factors) within the dataset (Siegel 2010; Brickey et al. 2012; Russell 2002). Use of either CA or FA/PCA requires developers to generate data in (or convert data to) numerical form. In contrast, LSA is a semi-automated qualitative clustering technique that determines the degree of similarity among word groupings by comparing textual documents (i.e. interview transcripts) against each other. Outputs of all semi-automated clustering techniques (i.e., CA, FA/PCA, and LSA) are quantitative. Drawbacks of semi-automated clustering approaches are the requirements for persona developers to have knowledge of statistical procedures and experience in interpreting statistical results and converting them into a textual form (Maness et al. 2008; Brickey et al. 2012; Miaskiewicz et al. 2008). Proponents of semi-automated clustering suggest that these techniques may help to overcome critical drawbacks of manual QC, namely human subjectivity and cognitive processing limitations, a need for qualified experts, and cost/time requirements (Mulder and Yaar 2007; Sinha 2003; Brickey et al. 2012; McGinn and Kotamraju 2008).

One primary study in this review (Kahraman 2010) described using qualitative content analysis for data reduction. The remaining four studies (Finelli et al. 2014; Pawley 2013; Turns et al. 2015; Zaugg and Rackham 2016) did not describe the approach employed for data analysis.

Physical Representations In keeping with the broader UX design literature, most (17/20) primary studies presented personas in the form of biographical narratives or dashboards of attributes, goals, and needs. Narrative personas commonly consisted of a written synopsis detailing the background, goals, attributes, and motivations of the persona. Dashboard personas typically included a short introductory paragraph with attributes and demographic information being provided using bullet points. Photo images and representative quotes were often used to add depth and personality to both narrative and dashboard personas. Sundt and Davis (2017) also produced and distributed persona pocket cards to help communicate their personas more broadly to library stakeholders. Lewis and Contrino (2016) went beyond persona representations by constructing corresponding "mental models" of library usage for each persona. In their study, mental models appeared physically similar to personas yet represented the thought process each persona engaged in when electronically accessing information stored within the library.

Assessment Persona assessment [or "persona validation" (Adlin and Pruitt 2010)], as a last step in the persona development process, is important for identifying flaws or missing information in personas and for evaluating a persona's potential for usefulness and impact. Common methods for assessing personas described by eleven primary studies include dissemination to stakeholders with feedback (Lilley et al. 2012; Chandler 1994; Finelli et al. 2014), usability tests (Sundt and Davis 2017; Chandler 1994), asking potential product users if/how they identify with personas (e.g., Turns et al. 2015; van Rooij 2012), comparing personas to subsequent data gathered after persona creation (Volentine et al. 2013; Tempelman-Kluit and Pearce 2014; Kahraman 2010; Sundt and Davis 2017; Zaugg and Rackham 2016; Miaskiewicz et al. 2008), and employing personas as design tools (e.g., Turns et al. 2015; Antle 2008). While assessment is indicated as an important step to persona development in the UX design

literature, nine primary studies did not describe efforts to assess the personas that were developed.

Research Question Three

To answer research question three, we examined primary sources to understand the ways in which product design tools have been used in combination as contextualized models of user experience within education settings.

Usage Model Conceptualization As a result of this review, we found that usage models have not been conceptualized or employed within the UX education literature; we did not find any studies describing employment or plans to construct multi-tool usage model structures, of any kind, within the broader UX education literature. Noting that it was not until the late 1990s that the term "usage model" was heard outside of Intel Corporation, Simmons (2006) provides a summary of the sparse literature related to the development and employment of usage models within the UX design community. Simmons (2006) work suggests that UX researchers have operationalized the term "usage model" differently and that, currently, no single or preferred conceptualization for combining design tools and/or contextualizing product usage currently exists within this community.

Application of Usage Models in STEM Education Despite lack of evidence of the employment of multi- tool usage models to describe contextualized student and/or faculty experience, our review did uncover evidence suggesting that researchers may be moving toward employing multiple tools for course/curriculum design in STEM education. Lilley et al. (2012), for example, described future plans to supplement their existing distance student personas with "scenarios of usage" that reflect distance students' approaches to learning. The authors discussed the need to complement existing personas with scenarios in order to ensure that online courses developers understand the distance student population as learners. Turns et al. (2015) reported that having access to "broadly useful," "relevant," and "contextually specific sets" of personas (e.g., persona sets related to student diversity, engagement, or self-regulated learning) were needed when assisting teachers with course design. They suggested that having access to a library of personas that have been developed around contextualized topics that commonly arise during instruction or student advisement would be valuable for STEM faculty and curriculum developers. Together, these pieces of evidence suggest that a combination of UX design tools that contextualize student experience may be even more useful for STEM course/curriculum design and development than stand-alone personas.

Conclusions

Increasing calls for instructional innovation and curricular change, particularly within STEM disciplines, are prompting scholars to explore new ways to usher evidence-based practices into classrooms and construct student-centered learning experiences. This review synthesizes the current body of interdisciplinary scholarship related to the

application of UX design approaches within education settings and offers recommendations for future research in this area.

As depicted in Fig. 4, the primary studies included in this review can be grouped into two categories related to the purpose for UX design implementation: to *design educational experiences* or to *design educational tools*. Eight of 20 primary sources can be categorized as having a purpose to *design educational experiences,* either through the work of (re)-designing curriculum and pedagogy, communicating research outcomes at higher administrative levels to promote change within academic and educational institutions, or analyzing (and communicating) data about faculty perceptions of specific, particularly student-centered teaching strategies. The remaining 12 primary sources can be categorized as having the purpose to *design educational tools* that benefit or improve the capabilities and/or outcomes of academic researchers, teachers, or students, such as web-based faculty productivity tools, library and online repository interfaces, or educational technologies. The majority (6/8) of primary articles that focused on the design of educational experiences were set within STEM education settings. Thus, growing scholarship related to the use of UX approaches to improve innovation and shrink the research to practice gap has potential to be a unique contribution of STEM education researchers.

As a result of this work, we offer the following conclusions and recommendations.

1. *Current scholarship shows potential for UX approaches to promote design of effective education experiences, specifically by informing curricular innovation and promoting communication of research findings for institutional policy change.* For example, STEM education researchers have reported that UX approaches to curriculum and instruction design helped to improve instructor understanding of student learning approaches and technology needs in online course settings (Lilley et al. 2012) and to promote discussions about teaching and learning among

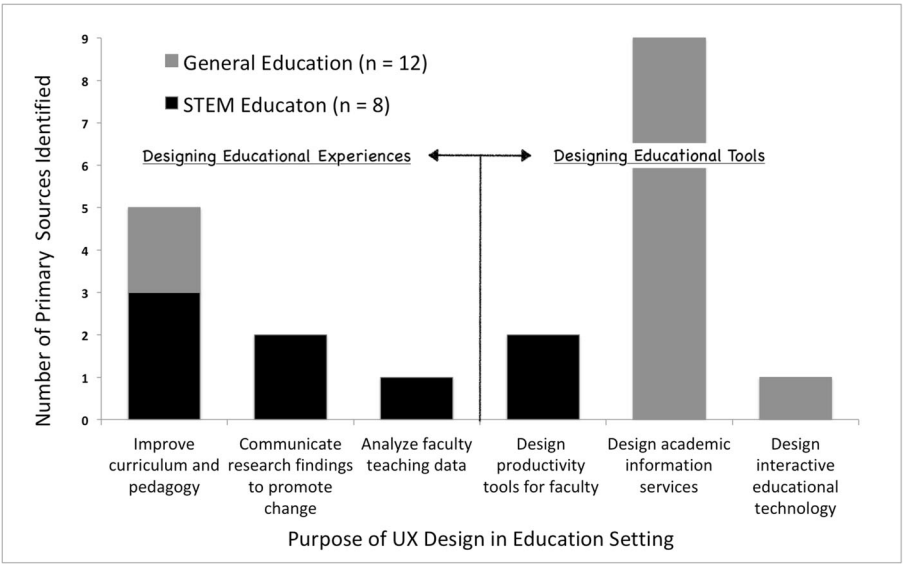

Fig. 4 Number primary sources ($n = 20$) by purpose for implementing UX design. Purposes can be grouped into two categories: design of educational experiences and design of educational tools

engineering educators, teaching assistants., and undergraduates (Turns et al. 2015). General education researchers found that UX approaches were useful for teaching professional design students about empathy (van Rooij 2012). Therefore, current literature provides adequate support for further exploration of UX approaches to promote instructional innovation. However, because this literature is descriptive and nonexperimental, future scholarship should focus on implementing assessment measures and reporting on assessment outcomes across a wide variety of contexts in order to inform advancement of UX approaches within education.

2. *Current scholarship suggests that the impact of UX approaches in education may be increased by combining and/or synthesizing multiple UX design tools into contextualized models of experience*. Current scholarship is based heavily on the (sole) use of personas to design of educational experiences; personas, as archetypal representations of users, are commonly presented in the absence of context. The work of a few STEM scholars (Lilley et al. 2012; Turns et al. 2015) point to the need for curricular tools contextualized around specific issues of critical importance in STEM education (e.g., diversity, metacognition, identity, etc.). New research could add to the field by exploring new ways to develop and represent contextualized UX models of experience within educational contexts.
3. *Current scholarship is nascent, interdisciplinary, and reliant on UX design methodological literature.* While UX education scholarship is presently limited, interest in employing UX design approaches to improve educational experience has been consistent within STEM education since 2011 and within general education since 2006 (Fig. 1). Because this work is interdisciplinary (Fig. 2), periodic reviews are needed to assess trends and outcomes and recommend new directions. With notable exceptions (e.g., Vorvoreanu et al. 2016; Antle 2008), we note a general trend within the literature to ignore the methodological detail of UX design tool development within the educational literature. Because readers of this scholarship must go to the UCD and HCI literature in order to understand methodological practices, this trend may inhibit advancement of UX design use within education. New UX education scholarship should focus on the development and documentation of a base of methods-based knowledge within its own literature, paying attention to any intricacies or complications that may occur when implementing UX approaches with data generated within educational contexts. In addition, new methodological approaches could be developed to reduce the time and cost associated with current UX based approaches.

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Compliance with Ethical Standards

Conflict of Interest Statement On behalf of all authors, the corresponding author states that there is no conflict of interest.

Appendix

Author/Title	Purpose of the work	Design tool	Analytic methods	Data collection	Representation (number)	Assessment
Primary Sources (STEM Education) (8)						
Chandler (1994). The science education advisor: Applying a user centered design approach to the development of an interactive case-base pedagogical advising system	To describe the application of user centered design principles to address representational and strategic issues during the conceptual design of an AI- based science advising system for elementary teachers	User model, task model, and domain model	QC	Interviews (QUAL)	–	Demonstrations for teachers, Usability tests
Guy (2017). Movers, Shakers, & Everyone in Between: Faculty Personas Surrounding Active Learning in the STEM Classroom	To examine STEM faculty attitudes toward active learning strategies.	Data driven personas	QC, Thematic Analysis	Modified Group Level Assessment (GLA) in an online format (QUAL)	Table (4)	–
Lilley et al. (2012). Understanding the Student Experience Through the Use of Personas	To develop a set of distance learner personas to guide online curriculum development in a distance-delivered computer science program	Ad-hoc, data driven personas Anticipated future use of scenarios	QC	Surveys, interviews (QUAL)	Dashboard format with images and quotes (5)	Dissemination and feedback from staff and developers
Finelli et al. (2014). Bridging the Research-to-Practice Gap: Designing an Institutional Change Plan Using Local Evidence	To use of personas to convey the Faculty stories as a way to gain administrative support for institutional change efforts	Data driven personas	–	Faculty Focus groups and classroom observation (QUAL)	Narrative with bulleted quotes and an image	Feedback from engineering faculty administra-tors
Pawley (2013). "Learning from Small Numbers" of Underrepresented Students' Stories: Discussing a Method to	To discuss the use of personas to analyze narrative research data on marginalized groups in engineering	Anticipated future use of data driven personas	–	–	–	–

(continued)

Author/Title	Purpose of the work	Design tool	Analytic methods	Data collection	Representation (number)	Assessment
Learn About Institutional Structure Through Narrative						
Turns et al. (2015). Exploring the Usefulness of Personas in Engineering Education	To examine the usefulness of personas to improve learning experiences in engineering education and to translate research data to engineering education stakeholders	Data driven personas Anticipated future use of contextual-ized sets of data driven personas	–	–	Narrative and Dashboard	Course design sessions with faculty and graduate students
Vorvoreanu et al. (2016). Designing for STEM Faculty: The Use of Personas for Evaluating and Improving Design	To develop STEM faculty personas to evaluate and refine the design of an interactive data analytics tool	Data driven personas, scenarios, use cases, and cognitive walk throughs	QC	Interviews (QUAL)	Narratives with images and bulleted items (Not Reported)	–
Vyas et al. (2006) Understanding the Academic Environments: Developing Personas for Field Studies	To analyze qualitative field study data generated among academic faculty in science and medicine in order to create structured and ordered information for use in design	Data driven personas	QC using MAXQD-A	"Ethnographic" methods: Interviews, diary keeping, and observations (job-shadowing) (QUAL)	Narrative with photo (unknown)	–
Primary Sources (General Education) (12)						
Antle (2008). Child-based Personas: Need, Ability, and Experience	To assess a framework for child-user abstractions that combine theory, empirical data, and goals for child experiences that is suitable for use during the design of interactive,	Data driven personas	QC (pattern analysis informed by	Interviews, observations, sessions with child experts (QUAL)	Narratives with images (6)	Implement framework to develop child personas and revise

(continued)

Author/Title	Purpose of the work	Design tool	Analytic methods	Data collection	Representation (number)	Assessment
	educational technologies for children		frame-work)			
Al-Shboul and Abrizah (2014). Information Needs: Developing Personas of Humanities Scholars	To demonstrate how personas can be used a research approach to better understand the information needs of humanities scholars	Data driven personas	QC	Interviews (QUAL) Demographics (QUAN)	Narratives with Images (4)	–
Kahraman (2010). Using User-centered Design Approach in Course Design	To describe the adaptation of user centered design approach to improve teaching and student success in three post-secondary elective courses related to interior design	–	Content analysis	Focus groups (QUAL)	–	Student Question-naires
Koltay and Tancheva (2010). Personas and a User-centered Visioning Process	To develop a set of personas based on primary clients of an academic library (faculty, graduate students, and undergraduates) to inform and assess the design of the academic library's online access platform	Data driven personas (10)	QC	Interviews (QUAL)	Combined narrative and dashboard with an image http://hdl.handle.	
net/1813/8302	–					
Lewis and Contrino (2016). Making the Invisible Visible: Personas and Mental Models of Distance Education Library Users	To understand gaps between users' and designers' mental models of digital libraries at a predominantly online university	Data driven personas	QC Empathy Maps	Chat and email transcripts, student and faculty posts (QUAL) Demographics, survey (QUAN)	Dashboard combined with narrative (4) Mental Models (4)	–
Maness et al. (2008). Using Personas to Understand the Needs and Goals of Institutional Repository Users	To develop personas of potential institutional repository users in order to inform the design of an online repository for an academic institution	Data driven personas	LSA	Interviews (QUAL)	Narrative with image (4)	–

(continued)

Author/Title	Purpose of the work	Design tool	Analytic methods	Data collection	Representation (number)	Assessment
Miaskiewicz et al. (2008). A Latent Semantic Analysis Methodology for The Identification and Creation of Personas	To describe a quantitative persona development methodology, based on latent semantic analysis of textual data, that is used to develop personas of institutional repository users at an academic institution	Data driven personas	LSA	Interviews (QUAL)	Narrative with image (1)	Interviews, surveys
Sundt and Davis (2017). User Personas as a Shared Lens for Library UX check sources	To propose a lightweight, budget friendly method of persona creation for the design of library web-based services at a land grant university	Data driven personas	QC	Reference Desk transactions, chat transcriptions, surveys, usability study results (QUAL)	Bulleted templates with photos (9); pocket cards with photos (6)	Interviews, usability testing, staff feedback
Tempelman-Kluit and Pearce (2014). Invoking the User from Data to Design	To design user-centered academic library services	Data driven personas	CA	Coded text-based online chat transcripts (QUAL>> QUAN)	Dashboard with image and quote (4)	Surveys, interviews, demographic trends
Van Rooij (2012). Research-based Personas: Teaching Empathy in Professional Education	To employ persona development, related to the design of a website for the parents/ families of children with special needs, to teach empathy to graduate students in an instructional design program	Data driven personas	QC	Focus groups (QUAL)	Narrative (1)	Survey of parent panel
Volentine et al. (2013). Portraits of Success: Building Personas from Scholarly Reading Patterns	To determine patterns in scholarly reading among successful young academics in the UK	Data driven personas	QC	Demographic Surveys (QUAN) Surveys (QUAL)	Narrative (3)	–
Zaugg and Rackham (2016). Identification and Development of Patron Personas for an Academic Library	To engage communication undergraduates, as part of their coursework, in developing personas for undergraduate library patrons	Data driven personas	–	Undergraduate library assessments Observations Interviews	Narrative description and a quote (10)	PCA

(continued)

Author/Title	Purpose of the work	Design tool	Analytic methods	Data collection	Representation (number)	Assessment
				Focus Groups "Ethnographic studies" (QUAL) Survey (QUAN) for PCA assessment		
Secondary Sources (Methodological) (18)						
Adlin and Pruitt (2010). The Essential Persona Lifecycle	Taking into account how the user navigates software and design software to that users need	Ad-hoc and data driven personas	QC	Census data (QUAN) Interviews, focus groups (QUAL)	Narrative and Dashboard (3–6 recommended)	Site Visits, disseminations
Brickey et al. (2012). Comparing Semi-automated Clustering Methods for Persona Development	To present an empirical study comparing quantitative cluster techniques (FA/PCA, Cluster analysis, and LSA) with manual qualitative clustering by experts	Data driven personas	Comparison of FA/PCA, LSA and QC clustering techniques	Online survey responses (open ended textual and numerical responses) and online knowledge management queries (QUAN and QUAL)	–	–
Carroll (1999). Five Reasons for Scenario Design	To motivate and present a framework for the use of scenarios during computer product design and development	Scenarios	–	–	Forward looking narrative stories	–
Cooper (2004). The Inmates are Running the Asylum: Why High Tech Products Drive Us Crazy and How to Restore the Sanity	To develop a precise description of a product user and their goals for use in technology product and software design	Ad-hoc personas	–	–	Narrative with an image (3–12 recommended)	Anti-persona
Ferreira et al. (2015) Designing Personas with Empathy Map	To assess the use of empathy maps for creating personas	Empathy Maps Data driven personas	QC	Provided descriptive scenarios	–	Surveys of student developers

(continued)

Author/Title	Purpose of the work	Design tool	Analytic methods	Data collection	Representation (number)	Assessment
Goodwin (2002). Getting from Research to Personas: Harnessing the Power of Data	To design interactive products with a user focus	Data driven personas	QC	Interviews, Observations (QUAL)	Narratives	–
Laurel (2003). Design Research: Methods and Perspectives	To present the idea of "qualitative design research"	Data driven personas	QC	Market research, Design research	–	–
McGinn and Kotamraju (2008). Data-Driven Persona Development	To describe a quantitative method for persona development, based on factor analysis of a statistically significant sample of qualitative data	Data driven personas	FA QC	Task surveys (QUAN) Interviews (QUAL)	Poster with image (11)	–
Mulder and Yaar (2007). The User is Always Right: A Practical Guide to Creating and Using Personas for The Web	To describe the development and use of personas during website design	Data driven personas	QC CA	Surveys, interviews, observations (QUAL) Usage Surveys Site traffic analyses (QUAN)	Narrative	Verify personas using log file user data and more surveys
Norman (2004). Ad-Hoc Personas and Empathetic Focus	To describe the development and use of personas during product design	Ad-hoc personas	Not Applicable	Not Applicable	Narrative (1)	–
Pruitt and Grudin (2003). Persona: Practice and Theory	To describe the development and use of personas for software design and evaluation	Data driven personas	QC	Market segmentation (QUAN) Market user research (QUAL)	Foundation documents with images, narratives, posters, flyers, handouts (3–6)	Dissemination Anti-persona
Putnam (2010). Bridging the Gap Between User Experience Research and Design in Industry. An Analysis of Two Common Communication Tools: Personas and Scenarios	To understand if personas with contextual scenarios are perceived as stable, useful and effective by user experience (UX) designers with a geographically distant audience	Data-driven personas with contextual scenarios	QC	Existing survey data (QUAN) and Focus group/Interview data (QUAL)	Narrative with bulleted information and picture (3)	Research

(continued)

Author/Title	Purpose of the work	Design tool	Analytic methods	Data collection	Representation (number)	Assessment
Rosson and Carroll (2002). Scenario-based Design	To describe how scenario-based design can be used to depict the future use of a system early in the development cycle	Scenarios	–	–	Narrative	–
Scupin (1997). The KJ Method: A Technique for Analyzing Data Derived from Japanese Ethnology	To describe a group-based method for analyzing ethnographic data	–	QC	Ethnographic data (observations, artifacts)	–	–
Siegel (2010). The Mystique of Numbers: Belief in Quantitative Approaches to Segmentation and Persona Development	To present a case study comparing quantitative market research segmentation and qualitative clustering of field (observational) data	Data driven personas	Market segmentation and QC	Market segmentation data (QUAN), in depth interviews and observational data (QUAL)	–	Verifying market segmentation with qualitative data
Simmons (2006). The Usage Model: Describing Product Usage During Design and Development	To describe a usage model framework for product design and development	Usage Model Framework	–	–	–	–
Sinha (2003). Persona Development for Information-Rich Domains	To develop personas for use in designing an online restaurant finder in the Bay Area using quantitative market data	Data driven personas	PCA	Market segmentation surveys, Market user research (QUAN)	Narrative with image and quotes (4)	Interviews, observations (QUAL)
Tu et al. (2010). Using Cluster Analysis in Persona Development	Case study describing the development of personas used to improve online travel services using QUAN (primary) and QUAL (secondary) data	Data driven personas	CA QC	Survey (QUAN) Interviews, observations (QUAL)	Combined narrative and dashboard with an image (2)	–

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