Essays on an Ecological Approach to User-Technology Interaction

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A Thesis

In the Department of

Supply Chain and Business Technology Management

Presented in Partial Fulfillment of the Requirements

For the Degree of

Doctor of Philosophy (Business Administration) at

John Molson School of Business

Concordia University

Montreal, Quebec, Canada

July 2016

CONCORDIA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

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Entitled: Essays on an Ecological Approach to User-Technology Interaction

and submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy (Business Administration)

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Essays on an Ecological Approach to User-Technology Interaction

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Concordia University, 2016

Abstract

This thesis consists of three essays that propose an ecological approach to look into various aspects of user-technology interaction. The overarching theme of the thesis is *the role of the technological artifact in how technology is understood and adapted by users in organizations*. Organizing is the social process of achieving goals, and it is always tied to the way people understand and adapt to their environment, including the information technology in that environment. The way people make sense of new technology in organizations and adapt it into their work routines brings extensive consequences to organizations. Despite the extensive body of literature examining the social and cognitive aspects of user sensemaking and adaptation to technology, there is little known about the role of the technological artifact in shaping user sensemaking and adaptation to new technology.

The first essay reviews and synthesizes the extant literature on how people understand technological phenomena in organizations. Then it highlights the three shortcomings of existing sensemaking research: the neglect of the role of the IT artifact, of the discovery part of perception, and of the role of the individual action. There is limited understanding on the role that the material artifact plays in shaping users' sensemaking of new technology, as well as how users' actions affect their sensemaking. Moreover, the literature mostly neglects the discovery aspect of sensemaking, that is, the perception of the meaning already available rather than creating new meaning to rationalize users' experiences. To address these issues, this essay provides a thorough review of literature on organization-technology sensemaking and synthesizes our current understanding of the phenomenon. Then it analyzes the major shortcomings in our knowledge and highlights the need to address those shortcomings. It subsequently discusses an ecological approach consistent with the tenets of critical realism that can address some of the existing shortcomings. The paper also offers some key implications of the ecological approach for research and practice.

The second essay addresses the role of the technological artifact in shaping users' understanding of technology (i.e. technology sensemaking). It proposes an ecological approach to technology sensemaking that focuses on the relation between users' perception of technology and the technological features to which they adapt. Moreover, it advances Information Systems (IS) research by providing new conceptual and analytical tools to examine the role of the IT artifact in IS research. To empirically illustrate the proposed approach and suggested methodology, we report the findings of an empirical study that applies and validates the framework.

The third essay focuses on the patterns of user adaptation to the technological artifact to contribute to research on user-centred system development. For more than a decade, the persona technique has been used in interface design practices to put user needs and preferences at the centre of all development decisions. A persona is a fictional character that represents potential users and what they want to accomplish. Persona development teams draw on qualitative or quantitative user data to develop representative personas. Despite the benefits of both approaches, qualitative methods are limited mostly by the cognitive capabilities of the persona developers, whereas quantitative methods lack contextual richness. To gain the advantages of both approaches, this essay suggests a mixed-methods approach to create user personas based on the patterns of affordances they actualize, rather than merely on the actions they take. It enriches personas by referring to the purposes fulfilled through affordance actualizations and grounds personas in readily available objective log data. This essay illustrates the practical value of the proposed methodology by empirically creating personas based on real user data. It also creates quantitative-only personas, presents independently developed qualitative-only personas, and compares them to the affordance-based personas to demonstrate the advantages of the suggested method.

The three essays together suggest and empirically illustrate an ecological approach to examine the role of the IT artifact in users' sensemaking of and adaptation to new technology. They contribute to research and practice by a) proposing the theoretical and analytical tools needed to examine users' sensemaking of technology in relation to their adaptation to the IT artifact, and b) suggesting the mixed-methods technique to create user personas based on the patterns of affordance actualization by users.

Dedication

To my parents, Zahra and Hossein

for their unconditional love

To my best friend and the love of my life, Maryam

the one and only

Acknowledgements

The journey through the doctoral program was certainly far more challenging than I ever expected, and it could not have been successfully accomplished without the contribution of many significant others who supported me throughout the way.

First, and foremost, I would like to thank my supervisor, Dr. Chitu Okoli, who supported me in every possible way that could be expected from an advisor. Chitu, you are the most helpful, understanding, patient, and dedicated advisor I could ever ask for. You were generous in sharing your knowledge and expertise and were understanding and supportive in letting me explore my ideas and push them forward; you set an example for me on how to advise students in my future career.

I would also like to thank the members of my doctoral committee, Professor Rustam Vahidov and Dr. Ana Ortiz de Guinea, who provided me with their valuable insights on various aspects of the thesis. My appreciation goes to Dr. Rilla Khaled and Dr. G Harindranath, who served as the examining committee members and enriched the thesis with their helpful comments. My special appreciation goes to Professor Samer Faraj, who not only served on my phase II doctoral committee, but also inspired me with some of his insights early in the thesis process and supported me throughout the program when I was unsure of my ideas and about the doctoral program. I would also like to thank Dr. Anne Beaudry, for serving on my phase II committee and commenting on some of the earliest drafts of my ideas. I extend my appreciation to the many faculty members who played a role in my training and especially to Professor Suzanne Rivard, Professor Alain Pinsonneault, Professor Ann Langley, Dr. Geneviève Bassellier and Dr. Liette Lapointe. I would like to thank Dr. Bijan Azad for his generous comments on certain aspects of the thesis. I also thank the anonymous reviewers of the AMCIS, ICIS, and AOM 2015 conferences, where the initial drafts of the three thesis essays were presented.

This thesis could not have been accomplished without the direct and generous contribution of the many students and instructors who voluntarily participated in the study and provided us with the needed data. My special thanks go to the enthusiastic students who took their time to meet with me and share their unique personal experiences with the system. I am very grateful to the many doctoral candidates and recent graduates who took part in various phases of this study, including

Dr. Maryam Tofighi, Hajar Fatemi, Dr. Kaveh Mohajeri, Dr. Hosein Maleki, Dr. Mahsa Kaviani, Dr. Bogdan Negoita, Dr. Mohammad Moeini Aghkariz, Dr. Bo Yu, Hamed Ghanbari, Arash Amirkhani, Dr. Ehsan Derayati and Dr. John Vongas. I also thank the many professors and instructors who cooperated in the process of this study, including Marc-Andre Leger, Dr. Wissam Nawfal, Dr. Chaher Alzaman, Dr. Sirage Alattas, Dr. Amir Hosseinipour, Professor Jamshid Etezadi, Professor Mahesh Sharma, Dr. Anne Beaudry, Professor Gregory Kersten and Professor Meral Büyükkurt. I also thank Barbara Cree who helped in the process of data collection. I extend my appreciation to Dr. Richard Cooper who proofread the final version of the thesis.

I am grateful to Concordia University and the John Molson School of Business for their support throughout the doctoral program and the generous funding for this research project. I also thank the Centre Desjardins d'innovation en financement d'entreprises, The Desjardins Group, for their support.

Lastly, and certainly the most, I am indebted for this successful journey to my family who have always supported me in any way possible. My mom and dad, Zahra and Hossein, always set education at the highest priority for the family and taught us the value of learning. They sacrificed a lot and gave up many opportunities throughout their lives so that we could get a good education and grow with values. I was extremely lucky to have my lovely wife and best friend, Maryam, as my intellectual companion during the doctoral program; she kindly shared her thoughts and insights and provided help when I needed it the most. She is both the mind to talk to and the heart to be comforted by.

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Introduction

Information Systems (IS) appear to be understood and adapted differently in various contexts, and this has extensive consequences for organizations. For instance, Lapointe and Rivard (2005) provided evidence of differing user adaptation behaviours, from adoption to passive and aggressive resistance, based on what people perceive when they start interacting with an electronic medical records system. Such differing adoption behaviours resulted in failure of the electronic medical records implementation projects in two hospitals, compared to another hospital that successfully delivered the project. The same software package succeeded in one hospital while failing in the others because of the very different perceptions and adaptive behaviours raised.

In another example, cab drivers in Singapore reportedly understood and used the GPS dispatching technology as either the "detector" of customers who requested a cab by phone or the "explorer" of new routes and hot-spots (Hsiao et al. 2008). While the first group could enhance the quality of service for the current customers, the second group could attract new customers; so they could help the company with either retaining or expanding its customer base.

Current information systems (IS) research takes various social and cognitive approaches to explain how users understand new technology (i.e. sensemaking) and adapt it into their working routines. However, *the role of the technological artifact in shaping user sensemaking and adaptation behaviour* has not been sufficiently examined. In an exemplary study, Griffith (1999) demonstrated that some aspects of technological features play a role in triggering the user sensemaking of new technology; the core and concrete features, versus the tangential and abstract ones, are more likely to trigger user sensemaking of the technology. Yet the IS literature marginally addresses the role of the information technology (IT) artifact in shaping user sensemaking of technology and how it is adapted in users' practices. Consequently, it is unable to adequately inform technology design to improve user sensemaking and the adaptation of technology into organizational routines. This highlights the need for new conceptual and analytical tools to be able to account for the role of the IT artifact in explanations of technological phenomena (Benbasat and Zmud 2003; Orlikowski 2010).

For instance, while the literature informs us on the "detector" and "explorer" understandings of GPS technology by the cab drivers and their implications for their system use and work practices (Hsiao et al. 2008), it is mostly silent on how the two understandings refer to the GPS features and design. Addressing this point would have important implications for managers and design practitioners. For one, managers of the cab companies could make informed decisions on promoting certain features of the GPS system to encourage the "explorer" understanding of the system if their strategy is to focus on expanding their customer base. For another, the system designers might highlight the related features to support either the "explorer" or "detector" understanding of the GPS system.

This thesis consists of essays that propose an ecological approach to look into the role of the technology artifact in various aspects of user-technology interaction. Ecology has a century-long history of analyzing how organisms evolve and adapt to their environment. We draw on ecology theory and ecological psychology to adapt and employ the concepts of species and niche, along with the theory of affordances, to examine users' interaction with and adaptation to the technological artifact. We suggest that users' perceptions of technology affordances are related to the technological artifact to which they adapt as well as to some characteristics of the users.

There are various conceptualizations of the affordance concept in the organization-technology literature. Organization research takes a highly sociological approach and conceptualizes affordances as social and contextual properties of the system-context environment (Leonardi 2011; Majchrzak et al. 2013; Zammuto et al. 2007). This view is consistent with the more social readings of Gibson's (1986) work that assume that affordances of the system change from one context to another and are highly dependent on how the system is mingled in practice and in work routines (Bloomfield et al. 2010; Chemero 2003; Zheng and Yu 2016). IS design research conceptualizes affordances as the relation between the system and the user. From that perspective, affordances are properties of the system-user environment; that is, affordances of a system may change from one user to another. The focus on the user and the system is consistent with the topic of IS design research, that is, improving design and facilitating user-technology interaction. Behavioural IS research conceptualizes affordances as the properties of the user-system-context environment, meaning that system affordances change from one user and context to another (Hutchby 2001). It takes into account the roles of the user and the context to explain

affordances and how they guide behaviour (Strong et al. 2014). For this thesis, we subscribe to the IS design research perspective that considers affordances as the relation between the IT artifact and certain user groups that adapt to and actualize the technology affordances, because such a conceptualization of the affordance concept is highly consistent with the focus of our study on user-technology interaction. While this approach does not reject the role of social context, it chooses to focus on the user and the IT artifact to define affordances and to leave the social complexities to the technology implementation phase rather than including it in the design phase.

Moreover, this thesis draws on the ecological concepts of species and niche to analyze the patterns of user adaptation to technology. It provides a new mixed qualitative-quantitative methodology to identify species with various affordance actualization behaviours to represent personas (i.e. fictional characters of potential system users) employed in the process of system design and development.

First Essay

The first essay is a literature review. It reviews and synthesizes existing research on organization-technology sensemaking and discusses three shortcomings in the current research: the neglect of the role of the IT artifact, of the discovery part of perception, and of the role of individual action. First, the existing research provides limited insight about the role that the material artifact plays in these processes. For instance, we know that taxi drivers may understand GPS technology as either "detector" or "explorer," and that these understandings influence their technology use and work practices in certain ways (Hsiao et al. 2008). However, we know very little about how these understandings are related to GPS features and design characteristics. Having such knowledge, the taxi service company could promote using the features that foster understanding technology as "detector" if its core strategy is to retain existing customers rather than attract new ones. Similarly, the technology developers could customize the GPS system to facilitate the use of GPS system as "detector" if they knew how this kind of understanding is related to the design characteristics of the technology; they could reinforce the desired understanding of technology by highlighting the related design features.

Second, the existing approaches neglect the discovery aspect of human perception. Perception is partly an interpretation of what is going on around us based on our mental models and experiences and partly a discovery of the existing meaning within those experiences. For instance, taxi drivers know that the GPS system supports both manual and automatic modes of dispatching; this kind of understanding is simply discovering the possibility and meaning that already exists in the system. However, they may interpret this possibility as either supportive of exploration or of detection of customers on the basis of their own preferences for risk taking. Such interpretations may vary widely across different drivers according to their personal characteristics and mental models. While existing research has already examined the interpretive aspect of perception in detail, the discovery aspect has been largely neglected.

Third, the dominant approaches lack action orientation in sensemaking theories. This is related to the neglect of the discovery aspect of perception. Whereas the interpretive perception is mainly based on individual mental models and previous experiences, the discovery perception is based on actions that people take to explore and understand the meaning already available in their environment. So, the neglect of the discovery aspect of perception leads to ignoring how people explore the existing meaning through their actions and exploratory behaviour. For instance, while we know that taxi drivers might interpret a GPS as a detector or as an explorer of customers, we know little about the specific actions and exploratory activities that they take to discover the existing meaning of the GPS in the manual and automatic dispatch modes. This first essay discusses the ecological approach and how it addresses these three shortcomings of technology sensemaking research.

Second Essay

The second essay seeks to examine the role of the technological artifact in shaping varied user understandings of new technology. It addresses the many calls for reviving the role of the material artifact in explanations of technological phenomena in organizations (Benbasat and Zmud 2003; Leonardi 2011; Orlikowski and Iacono 2001). This article presents *Ecological Technology Sensemaking* (ETS), which focuses on the relation between users' perceptions of technology and their technological settings. ETS posits that what people understand about a new

technology are *affordances* (Gibson 1977), that is, the functional relationships between the material artifact and the individual (Faraj and Azad 2012; Leonardi 2013a). As an example of this point of view, GPS technology affords drivers the ability to "detect" customers already booked online and to "explore" new routes and hot-spots. However, the technology does not provide affordances to everyone equally, but rather depends on individual characteristics. The GPS technology may afford the drivers the ability to "explore" new routes and hot-spots only if they are risk-takers.

Our ETS perspective adapts the concepts of ecological niche and species to organization-technology research to facilitate the examination of the relationship between the user and the material artifact. A *technological niche* (*technoniche*) is the part of the technological setting and resources to which the user adapts; it represents the way the user lives in the technological setting. A *user species* is a group of users who adapt to the same technoniche. The concepts of technoniche and user species permit the conceptualization of users and material environments in relation to each other. ETS suggests that the affordances people explore, or the meanings they make, are related to the technological niche to which they adapt. In other words, users who belong to the same species explore similar meanings.

The contribution of this second essay is twofold. First, it complements the social and cognitive approaches to technology sensemaking by further theorizing the role of the technology artifact. This helps technology designers and managers to make informed decisions about how to design and implement the system to support certain sensemakings of new technology. Second, it extends technology materiality research by providing new conceptual and analytical tools to examine the role of the technology artifact in IS research. The innovative combination of the methodological tools suggested here enables IS scholars to examine various aspects of user adaptation to new technology. To empirically illustrate the proposed approach and suggested methodology, we report the findings of an empirical study on students using Moodle, a learning management system, in a North American business school. Use of a student sample is suitable for this study because 1) the student sample is not a proxy for any population, but it is the actual professional user group of the purposefully chosen system (Moodle) that we study; and 2) we do not intend to generalize the findings of the study beyond the student user group of this particular implementation of Moodle, but we only use it as an illustration of the proposed approach.

Third Essay

While the second essay examines the role of the IT artifact in users' sensemaking of new technology, the third essay focuses on its role in the later phase of user-technology interaction, that is, users' adaptation to technology. It draws on ecological ideas to provide a mixed qualitative-quantitative methodology for analyzing the patterns of user adaptation based on affordance actualization. For a decade, the persona technique has been used in interface design practices to put user needs and preferences at the centre of all development decisions. A persona is a "precise description of a user's characteristics and what he/she wants to accomplish" (Chang et al. 2008, p. 439). Persona development teams normally draw on either qualitative or quantitative data (but rarely both) to develop representative personas based on either user demographics (e.g. age, occupation, and education), psychographics (e.g. lifestyle, goals, and intentions), or user behaviour. Despite the benefits of both methods, qualitative methods are mostly limited to a few users' information, and quantitative methods that are based only on user log and survey data lack richness and context. To gain the advantages of both methods, we draw on ecological ideas of affordances and user species to develop a mixed-methods approach for creating user personas based on the pattern of affordances they actualize, rather than merely the actions they take. It enriches personas qualitatively by referring to the purposes fulfilled through affordance actualizations, and it grounds personas quantitatively in readily-available objective log data.

To illustrate the applicability and value of the new approach, we first collected and analyzed data to create Moodle user personas using the affordance-based approach that we present. Then, to illustrate the relative value of this new approach, we also used best practices to create personas based on only quantitative analysis of our dataset; and we also analyzed our interview data from the perspective of three independently-developed Moodle user personas using only qualitative analysis. The affordance-based personas demonstrate some significant advantages over existing approaches. First, they are grounded in and representative of the data from a large sample of users, unlike qualitative-only personas. Second, their development does not require the intense

qualitative skills of qualitative-only personas. Third, they provide the context about the personas over and above the actions they take, unlike quantitative-only personas. Fourth, they are less about who the users are and more about how and why they use and interact with the system and for what purpose they do so. This results in personas that are more readily usable and insightful in making the design decisions. Fifth, they provide the behavioural patterns of the personas, rather than presenting merely a number of behavioural or demographic variables associated with them. This provides further insight for making design decisions that support the personas. Sixth, they address the limitations of the current mixed-methods approaches by identifying personas using both quantitative and qualitative data, rather than identifying personas quantitatively and enriching them qualitatively, as is done by current methods.

Together, the three essays propose and empirically illustrate an ecological approach to examine the role of the IT artifact in user-technology interaction. While the first and second essays focus on the earlier phase of user-technology interaction, that is, user sensemaking of technology, the third essay looks into the later phase, namely, user adaptation to technology. The first essay reviews the current approaches to user sensemaking of technology and highlights the need to recognize and examine the role of the IT artifact. The second essay addresses the issue by suggesting and empirically illustrating an ecological approach by examining users' sensemaking of technology in relation to their adaptation to the IT artifact. The third essay examines the role of the IT artifact in user-adaptation to technology. It proposes and empirically illustrates a new technique to analyze patterns of user adaptation to the IT artifact on the basis of their actualization of the technology affordances.

This thesis bridges the behavioural IS research and the design-oriented Human-Computer Interaction (HCI) research to bring fruitful insights for both. HCI research is mostly concerned with better design of systems that are readily understandable to and easily usable by the target users (Norman 1999, 2002); so it is very much focused on analyzing how the users interact with the system and how to better design the system interface to facilitate their interaction (Vicente and Rasmussen 1990, 1992). In contrast, IS research is concerned with how the system is actually used and adapted into work routines to produce consequences for individuals and organizations (Benbasat and Zmud 2003). However, both streams of research analyze patterns in user adaptation to technology that are used in HCI research to improve system design (Cooper

1999; Johansson and Messeter 2005) and in IS research to enhance user adaptation and facilitate technology implementation (Ortiz de Guinea and Webster 2013). For IS research, this study provides a way to analyze user behaviour in relation to the IT artifact. For HCI research, it suggests analyzing user action data at a more behavioural level in terms of the affordances that users actualize.

This dissertation contributes to the current literature in two ways. First, it adds to the IS adaptation research (Barki et al. 2007; Ortiz de Guinea and Webster 2013; Sun 2012) and complements the current socio-cognitive approaches to user-technology interaction. It examines the role of the technology artifact in user sensemaking of technology. It can inform technology design practitioners on how user sensemaking and adaptation to technology are related to various features of their design. Second, it contributes to IS research and practice by providing the novel conceptual and analytical tools needed to examine the relation between user and the technological artifact. The concept of user species is a novel level of analysis at which we can theorize the relation between user and the IT artifact. The concept of technological niche, along the methodological tools to measure it, can help scholars to investigate user adaptations to the technological artifact.

Essay 1: Organization-Technology Sensemaking Research: Review of the Literature

ABSTRACT

Organizing is the social process of achieving goals, and it is always tied to the way people understand their environment. Sensemaking is the process of attributing meaning to experiences. More than two decades of sensemaking research have brought thorough knowledge of how people understand organizational phenomena and attach meaning to them. This stream of research explores varied social and cognitive aspects of the process in the context of organizations and of information technology. However, such a large body of literature exhibits some significant shortcomings: there is a lack of technology materiality; a neglect of the discovery aspect of perception; and a lack of action orientation. So, there is limited understanding of the role that the material artifact plays in shaping users' sensemaking of new technology, as well as how users' actions affect their sensemaking. Moreover, the literature mostly neglects the discovery aspect of sensemaking that refers to perception of the meaning already available rather creating new meanings to rationalize user experiences. To address these issues, this essay provides a thorough review of the literature on organization-technology sensemaking and synthesizes our current understanding of the phenomenon. Then it analyzes the major shortcomings in our knowledge and highlights the need to address those shortcomings. It subsequently discusses an ecological approach consistent with the tenets of critical realism that can address some of the existing shortcomings. The paper also offers some key implications of the ecological approach for research and practice.

An earlier version of this essay was presented as: Mesgari, Mostafa (2015). Ecological Approach to Technology Sensemaking. Presented at the Organizational Communication & Information Systems (OCIS) Division Professional Development Workshops for the Academy of Management Meeting. August 7-11, 2015, Vancouver, Canada.

INTRODUCTION

> The first project assistant, Jean, basically views ProjectWeb as a *broadcast* medium and this notion pervades her thinking about how to design, manage and use the project web sites, which she is responsible for. For Maria, the other project assistant, ProjectWeb is rather a kind of *groupware* system, which may support cooperation and interaction in her projects. (Bansler and Havn 2004, p. 71)

Like other organizational phenomena, technology is equivocal by its nature and can be understood in various ways and used accordingly (Weick 1990). For instance, ProjectWeb is a web-based groupware system that supports file and document sharing, information publication and group messaging. While Jean in the epigraph understood the ProjectWeb technology as a broadcasting medium and used it accordingly, Maria understood it as a collaboration support medium and used it thus. There are several other instances of technologies understood and enacted in various ways by organizational members; they include technologies like First Class (Henfridsson 2000), Lotus Notes (Karsten 1995; Orlikowski and Gash 1994), group decision support (Gopal and Prasad 2000), e-mail (Barley et al. 2010; Fulk 1993; Markus 1994), enterprise accounting (Svejvig and Jensen 2013), healthcare computer systems (Prasad 1993; Savoli and Barki 2013; Siino and Hinds 2005), and business-to-business (B2B) technologies (Barrett 1999; Mishra and Agarwal 2009), each of which is understood and interpreted differently by various members of an organization.

Such equivocality brings about significant intended and unintended consequences for individuals and organizations (DeSanctis and Poole 1994; Mishra and Agarwal 2009). For instance, taxi drivers provided with GPS dispatching technology in Singapore used the technology in very different ways, resulting in varied consequences for the company (Hsiao et al. 2008). Drivers who understood the GPS technology as a "detector" of customers who had called the dispatch centre to request a taxi could enhance the quality of service given to the existing customers of the company. However, the drivers who understood it as an "explorer" of new routes and hot-spots could attract new customers found in their explorations. In this case, varied understandings of GPS technology among taxi drivers could result in either retention or expansion of the company's customer base. Such intense implications of the phenomenon highlight the

importance of examining how people come to varied understandings of new technology in organizations.

Technology sensemaking is the process through which individuals and collectives come to an understanding of new technology and attach appropriate meaning to it (Gephart 2004). It starts when people encounter a new technology or updated versions of an old one and ends where the process of structuration of technology within the social system begins. In other words, it is the very initial phase of Information Technology (IT) introduction and implementation in organizations through which people get to know the technology, develop beliefs and attitudes towards it, and make up their minds about how it can be appropriated to do the task; this process feeds the adaptation and structuration processes that shape the technology-in-use crafted for a certain situation (Griffith 1999). (In this study, we use the terms "IT" and "technology" interchangeably.)

Organizational scholars have studied sensemaking processes and developed a coherent body of knowledge about how individuals and groups interpret and make sense of organizational phenomena, including technologies (Faraj et al. 2004; Griffith 1999; Maitlis 2005; Orlikowski and Gash 1994; Weick 1990). This stream of research thoroughly informs the cognitive processes through which people develop the mental models, called representations or frames, that attach meaning to the flux of individual experience. These frames include the assumptions, beliefs, and attitudes of the individual about the phenomenon at hand; they provide the necessary mental structure for making the meaning and attaching it to the individual experience. Sensemaking is the ongoing process of developing, adapting, and maintaining mental representations and frames according to individual experiences. Organization-technology research examines how organizational stakeholders make and maintain these frames and identifies the practices that managers employ to influence their employees' frames and their understanding of the organizational technology and other phenomena. In addition, it considers how frames correspond to varied uses and consequences of technology in organizations (Orlikowski and Gash 1994).

Although the dominant cognitive approach to technology sensemaking sheds light on many cognitive processes of understanding technology, it neglects three other aspects of the

phenomenon: the role of the material artifact, the discovery aspect of perception, and the role of action in sensemaking research.

First, it provides limited insight about the role that the material artifact plays in these processes. Technology materiality is of key importance, especially at the early stage of technology introduction and sensemaking because it is almost the only thing on which new users can draw to make sense about the technology while the rules and conventions of use are not yet shaped (Hallerbach et al. 2013). For instance, we know that taxi drivers may understand GPS technology as either "detector" or "explorer," and these understandings influence their technology use and work practices in certain ways (Hsiao et al. 2008). However, we know very little about how these understandings are related to GPS features and design characteristics. Better understanding this phenomenon could be quite consequential for both the organizations and for the technology developers. Having such knowledge, the taxi service company could promote using the features that foster understanding technology as "detector" if its core strategy is to retain existing customers rather than attracting new ones. Similarly, the technology developers could customize the GPS system to facilitate the use of GPS system as "detector" if they knew how this kind of understanding is related to the design characteristics of the technology; they could reinforce the appropriate understanding of technology by highlighting the related design features.

Second, the existing approaches neglect the discovery aspect of human perception. Perception is partly an interpretation of what is going on around us based on our mental models and experiences and partly a discovery of the existing meaning within those experiences. For instance, taxi drivers know that the GPS system supports both manual and automatic modes of dispatching; this kind of understanding is simply discovering the possibility and meaning that already exists in the system. However, they may interpret this possibility as supportive of either exploration or detection of customers on the basis of their own preferences for risk taking. Such interpretations may vary widely across different drivers according to their personal characteristics and mental models. While existing research has already examined the interpretive aspect of perception in detail, the discovery aspect has been largely neglected.

Third, the dominant approaches lack the action orientation in sensemaking theories. This is related to the neglect of the discovery aspect of perception. Whereas the interpretive perception is based mainly on individual mental models and previous experiences, the discovery perception

is based on the actions people take to explore and understand the meaning already available in their environment. So, the neglect of the discovery aspect of perception leads to ignoring how people explore the existing meaning through their actions and exploratory behaviour. For instance, while we know that taxi drivers might interpret a GPS as a detector or as an explorer of customers, we know little about the specific actions and exploratory activities they take to discover the existing meaning of the GPS in the manual and automatic dispatch modes.

This study seeks to examine ***how people understand the organization-technology phenomenon and ascribe meaning to it; the shortcomings in our current knowledge of the phenomenon; and how we can address these shortcomings.*** Since sensemaking activities feed the structuration processes and result in technology consequences for organizations, extending our knowledge of the phenomenon can contribute to other streams of research in technology adaptation and its consequences in organizations. In addition, this study clarifies how the design of the material artifact could play a role in technology adaptation processes in organizations. It thoroughly reviews and synthesizes the existing research on organization-technology sensemaking and takes the initial step to proposing a new approach to account for some of the current shortcomings. Drawing on ecological psychology, this study proposes the general foundation of an ecological approach to technology sensemaking. It facilitates a shift from traditional structurational Information Systems (IS) research to a critical realist perspective. The dominant cognitive psychology examines the mental processes through which people "make" meaning by categorizing and labelling stimulus information into meaningful categories. However, ecological psychology focuses on the meaning which exists in the environment and how people "explore" that meaning through their actions. In other words, the ecological approach focuses on the "exploring" aspect rather than on the "making" aspect of sensemaking processes. It suggests that what people understand about a new technology are *affordances*, that is, the functional relationships between themselves and the material artifact. From this point of view, GPS technology affords drivers the ability to "detect" customers already booked online and to "explore" new routes and hot-spots. However, the technology does not provide affordances to everyone equally; rather, they depend on individual characteristics. For example, the GPS technology may afford the drivers the ability to "explore" new routes and hot-spots only if they are risk-takers.

This paper contributes to the technology sensemaking research in multiple ways. First, it reviews and synthesizes current research on organization-technology sensemaking. It recognizes four major streams of organizational sensemaking that study sensemaking and sensegiving at the individual and collective levels. It also identifies two conceptualizations of organizational sensemaking, as schema and as narrative. Moreover, it discusses two major streams of technology sensemaking, including sensemaking through and about technology.

Second, this study highlights three important shortcomings of the current sensemaking research. One is that the socio-cognitive approaches do not address the role of the IT artifact in shaping user sensemaking of new technology. Another shortcoming is that while the cognitive aspect of sensemaking is well examined, the non-cognitive discovery aspect has been only marginally studied. The discovery aspect of sensemaking refers to the process of discovering the meaning that already exists in the environment, rather than creating new meanings to rationalize experience. The last shortcoming that we highlight is that while we know much about how sensemaking affects users' actions, we know very little about how users' actions affect their sensemaking.

Third, this study discusses the basic foundations of an ecological approach to sensemaking that addresses the shortcomings of current socio-cognitive approaches. It examines individual sensemaking in relation to adaptation to the technological artifact. Moreover, it contributes to IS research by facilitating a shift from the traditional structurational perspective to the recently developing critical realist one. It recognizes the three-layer stratification of real-actual-empirical of the technology sensemaking phenomenon, and it identifies affordances as generative mechanisms that shape users' sensemaking of new technology.

This paper starts by describing the review procedure we followed. Then it thoroughly reviews and synthesizes current literature in three major sections: what is sensemaking?, sensemaking in organization research, and sensemaking in technology research. Next, it follows with a thorough discussion that identifies the three major shortcomings of the sensemaking literature and explains how an ecological approach to sensemaking can address them. To seal the discussion, we elaborate on the implications of an ecological approach for research and practice with concrete examples of the insights from the new approach. The paper concludes with remarks on the past of technology-organization sensemaking research and an alternative way forward.

SENSEMAKING: A LITERATURE REVIEW

Sensemaking research spans various fields, including psychology, communications, organization studies, information systems and computer science. To inform this study on technology sensemaking in organizations, we restricted the scope of the literature review provided here to the organization and information technology domains. So, we looked for peer-reviewed journal publications that address any aspect of the sensemaking phenomenon in the context of organizations or information technology; this search included studies that examine the antecedents, the processes, or the consequences of individual or group sensemaking of organizational or technological phenomena.

To identify the relevant literature, we conducted multiple steps of literature searches over a period of time. We first began in 2014 and repeated the steps a number of times, most recently in June 2016, to identify and include recently published articles. We searched the EBSCO Host research database including all its composite databases for any of the words "sensemaking", "sense making", "sense-making", "sensegiving", "sense giving", or "sense-giving" plus the term "information technology" in the title, abstract, or keywords; we restricted the search to peer-reviewed journal publications. This search resulted in 107 items, of which 75 were unique. To identify the relevant studies, we read the title and the abstract and, in many cases, skimmed the full paper if needed. We identified and excluded irrelevant studies for any of the following reasons: 1) sensemaking was used and examined as a peripheral topic to the study rather than as a major one; or 2) sensemaking was studied in a context other than organizations or information technology. After carefully examining the identified items, 34 publications were retained as relevant to our study.

To make sure we did not miss any recent relevant studies, we complemented the collection by searching for peer-reviewed journal publications in the repositories of the Academy of Management Publications and the Association for Information Systems Electronic Library plus the *Information Systems Research* journal from 2004, which included more than a decade of recent studies and sufficiently addressed the purpose of our complementary search. Since these journals specifically focus on management or information systems, we used only the search term "sensemaking" and then manually screened out unsuitable articles when reading the abstracts. We searched within the title, abstract, and keywords of the journal articles when possible; we

read the abstracts and included 20 more papers related to sensemaking in the organizational or technology contexts.

Next, we did forward and backward citation searches looking for the studies cited in or by the included publications. As we read the literature, studies cited in multiple papers or that were influential in shaping any of the emerging streams of research were also added, including some important conference papers and book chapters. These processes resulted in the addition of 47 additional relevant studies. In all, we identified and reviewed 104 unique peer-reviewed publications relevant to the sensemaking phenomenon in organizational and technological contexts.

We started synthesizing the identified research by reading each publication in our collection and taking notes about the focus and contribution of the study. After a while, categories of studies started to emerge from our notes. We continued to extend and modify the categories to incorporate each subsequent study we examined. We had to go back and forth between our notes and the current categorization of the studies to be able to make sense of the emerging streams. The content of the organizational and technology sensemaking sections of this review paper is organized around the major streams that gradually emerged during the in-depth study of the relevant research, with four streams of organizational sensemaking research, and two streams of technological sensemaking studies.

We present the results of the review in the following three main sections. The first of the three sections discusses what sensemaking is essentially about, including sensemaking processes and properties. The second section reviews various aspects of sensemaking and sensegiving in organization research at the individual and collective levels; it also discusses two major conceptualizations of sensemaking in organization research. The last section reviews sensemaking in IS research, including sensemaking though technology and sensemaking about technology. After this review, the shortcomings in the current approaches to technology sensemaking are discussed to provide the basis for proposing a new, fruitful approach.

What Is Sensemaking?

Sensemaking is the process of "attributing meaning to surprises" (Louis 1980, p. 241), or more precisely, it is "the ongoing retrospective development of plausible images that rationalize what

people are doing" (Weick et al. 2005, p. 409). The notion of experience not only includes individual actions, their environments and events, but also the new data and information that people receive and need to understand. Sensemaking is the process through which people create meaning and attach it to what they experience. It can bring significant consequences to the individual and organization. For instance, employees of two North American banks reportedly made sense of the new account management system in one of two ways for their job: as a controllable opportunity or as an uncontrollable threat. As a result, the former used and benefited from the system maximally, while the latter used the new system marginally to reduce the disruption it could cause (Beaudry and Pinsonneault 2005). In the following, we discuss in detail the processes and properties of the sensemaking phenomenon.

Sensemaking Processes

The cognitive approach to human perception gives a cognition-based explanation of human behaviour in the environment. In a familiar, non-surprising situation, individuals seem to behave in an automatic and subconscious way, guided by cognitive models already developed within their individual minds (Louis 1980). Such cognitive models represent what the individual has learned about how the elements of the environment are related to events; the models store our knowledge about our environment and us and shape our expectations of actions and their results in the environment. Cognitive models include schemas (Weick 1979), scripts (Abelson 1981), representations (Vaast and Walsham 2005), frames (Orlikowski and Gash 1994), attributions (Ross 1977), and accounts (Scott and Lyman 1968). Although these various types of mental models are differentiated in some ways, they are very closely connected concepts representing individual mental models about how things relate to each other and to us.

In unfamiliar, surprising situations, the already-developed cognitive models would not be able to guide human behaviour, because the result of the individual action would be different from what the models suggest (Weick 1995). This is where the sensemaking processes starts: the individuals start looking for the reasons and explanations of why the cognitive models fail. In other words, sensemaking is triggered when there is a disruption, which is any distance between what is expected and what has already happened. Ambiguity may be the other factor that triggers the sensemaking process. Ambiguity mostly arises when the current mental models cannot

explain the ongoing event, thus the individual would have to look for updated or new cognitive models to explain the situation.

Figure 1-1 represents the process of individual sensemaking. When the sensemaking process is triggered by interruption or ambiguity, the person has to make conscious deliberations, draw on salient cues, and enact some sort of meaning. "Noticing" and "bracketing" are components of the enactment phase (Weick et al. 2005). When the process starts, the person notices the cues in the situation and brackets the salient part of their experience. Then the individual labels the bracketed cues by categorizing them into meaningful functional groups. Enactment is the phase in which the meaning is made and attached to the salient part of individual's experience, though multiple possible meanings may be related to some cues in this phase.

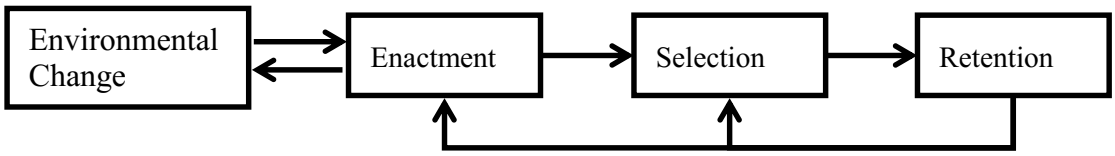

Figure 1-1. The sensemaking processes:
Adapted from: Weick et al. (2005)

Moreover, action is an inseparable part of the enactment phase (Weick et al. 2005). Most of the time, individuals do not passively perceive what is going on, but proactively participate in their experiences to be able to extract the cues and label them with appropriate possible categories of meaning. Individuals' action not only facilitates the process of making meaning, but also initiates changes in their environment.

Selection is the phase through which the one most plausible meaning is chosen to refer to the phenomenon in question (Weick et al. 2005). Rather than correctness, plausibility is the criterion that drives the selection phase; what the individual needs is a locally reasonable story that explains the new situation, rather than the "true" story. To be plausible, any story needs to be consistent with the significant identities of the individual (Weick 1995). Selected meanings do not necessarily survive through the retention phase of the sensemaking process; even if they do, they may not play a significant role in defining human behaviour until they are stabilized and

substantiated in cognitive mental models. Retained cognitive models later feed the enactment and selection phases of sensemaking processes by providing the mental models needed for enactment of new meanings and selection of the plausible ones.

In summary, the sensemaking process is triggered by changes in the individual's environment that cause an interruption in the flow of human experience; it may also be started by an ambiguous situation not interpretable through existing mental models. In such cases, individuals get the raw perceptual data from their environment by acting on the environment during the enactment phase and attribute possible meanings to the equivocal data on the basis of their previously developed cognitive schema that match the situation. The meaning that makes the most plausible story survives through the selection phase. The retention phase stores the successful sensemaking to be retrieved later. Karl Weick describes the process of sensemaking as the following, which is depicted in Figure 1-1 as well.

> When something unexpected occurs and there is an *environmental change*, people often *enact* something, *select* portions of the enactment to take seriously, and *retain* some meaning of what they enacted. Subsequently, they may then apply or alter what they retain in their next enactments and selections. (Weick 2000, p. 95)

Sensemaking Properties

There are multiple properties accounted for in sensemaking processes. These properties clarify the various aspects of the sensemaking phenomenon as it is studied by organizational scholars. Sensemaking is identified as an ongoing process of actively making meaning about what is going on around us, and it is deeply affected by the individual's identity construction. It may create meaning about what happened in the past (retrospective) or what is going to happen in the future (prospective). It is more about the plausibility of the meaning than its correctness. Sensemaking occurs not in isolation but in social interaction with others, so people are affected by and influence others' sensemaking. Lastly, people enact the meaning by acting in the environment and extracting and categorizing the cues. In the following subsections, we discuss each of these sensemaking properties in detail.

Ongoing Process

First of all, sensemaking is a *process* rather than a product. It should be noted that it is *ongoing* anytime and anywhere an individual faces new situations that require conscious comprehension (Weick 1995). Unless the behaviour is automatic, all human behaviour has to go through the process of sensemaking to be guided by the renewed and appropriate cognitive models. Moreover, sensemaking never stops because individual mental models are never final and need endless modifications to reflect the changes in the environment and the individual.

Identity Construction

Secondly, the sensemaking process is about constructing and maintaining individual *identities*. In fact, an individual's definition of the "self" and that of what is "out there" interact and influence each other, and this is why sensemaking of the environment is deeply grounded in one's identity (Weick 1995, p. 20). This differentiates sensemaking from other cognitive processes. The way in which the individual defines the self or their identity affects how they perceive and understand the external world and how they behave towards that world. When enacting new meanings, a person would be hesitant to bracket their experiences and label them in categories inconsistent with their definition of their self, because such inconsistency could raise psychological tensions and create dissonance. Even if bracketed, such meaning categories that are inconsistent with the individual's identity rarely have the chance to stabilize in the form of cognitive models because the behaviours that result from such models would weaken the individual's image and identity.

Retrospective and Prospective

Making and ascribing meaning is an "attentional process," and attention is directed towards an event that has already occurred. People cannot make sense of an event unless they have experienced it at some time in the past, and this is what makes sensemaking a retrospective process (Weick 1995, p. 26). However, retrospective sensemaking cannot account for the specific ways in which people assign meaning prospectively (Gioia and Mehra 1996; Weick et al. 2005). Sensemaking could be prospective when people make sense of something to be able to act on it later. Thus, the sensemaking process is partly a *retrospective* cognitive process that requires reflection and deliberation on past experiences and partly a *prospective* process that plans for future actions by anticipating their outcomes. While retrospective sensemaking reflects

on previous actions to understand the current ambiguity, prospective sensemaking pictures the scenarios for future actions to anticipate the resulting outcomes and plan for them. Whereas retrospective sensemaking is based on the previous actions of the individual, prospective sensemaking feeds the choices of future actions which in turn may trigger a retrospective sensemaking process (Stigliani and Ravasi 2012). Prospective sensemaking can be used by technology development teams to make design choices for a system being created (Jacobs et al. 2013) or by senior managers to make strategic decisions (Ravishankar and Pan 2013).

Plausibility

Sensemaking is more about enacting a *plausible* story than a "correct" one. Although a sense of accuracy is needed, the plausible story does not necessarily have to be accurate; accuracy plays at most a secondary role here. A story is plausible when it persuasively explains the ongoing flow of experience, demonstrates consistency with other data and stories, facilitates action, reduces ambiguity, gives a sense of correctness, and offers a fruitful future (Helms-Mills 2002). A story may be plausible for one group but not for another. For instance, a story may be plausible for employees, but not for managers, depending on their mental models, the data and information they have, and the situation they are in. When making sense of a new experience, people look for explanations that reduce the equivocality and best fit what they already know.

Sociality

Sensemaking is not solely a cognitive process that happens in isolation from the context and from other people. It is a *social* process through which the individual interacts with others and with the context to create the appropriate meaning. To make sense of a new situation, one draws not only on her or his social interactions with others, but also on her or his social capital and resources, such as centrality and closeness to power positions (Ibarra and Andrews 1993). This social process creates the basis for sensegiving activities through which powerful mediators influence how other people make sense of a specific situation. Such mediators manipulate the social environment and provide the cognitive resources that support their own specific sensemaking (Bartunek et al. 1999; Rouleau 2005). Moreover, the social aspect of the sensemaking process is even more profound when there is a collective of people making shared sense of the phenomenon. Concepts like shared understanding, shared sense, and consensus refer

to this social aspect of collective sensemaking. For instance, the crisis management teams (Weick 1988) and healthcare provider teams in hospital emergency departments (Paul and Reddy 2010) have to make collective sense about an urgent situation in a limited time frame; thus rich social interaction is of critical importance.

Making/Enacting Meaning

As one of the key aspects of his theory, Weick believed that sensemaking is about "enacting" the sensible environment rather than just pure sensing; he asserts that "enactment is first and foremost about action in the world, and not about conceptual pictures of that world" (Weick 1995, p. 36). To enact the appropriate meaning, people take action, extract the salient cues, categorize them, and label them with new tags specifying their functions. Individual cognition and action play major roles in the enactment of proper meaning.

Initially, Weick (1969) was concerned that the "creation" aspect of perceptual processes had been less appreciated, and thus he highlighted the point that "perception *creates* as well as reacts to an environment" (p. 39). He emphasized the creation aspect of sensemaking embedded in the enactment phase of the process. From this point of view, sensemaking "is less about discovery than it is about invention. To engage in sensemaking is to construct, filter, frame … and render the subjective into something more tangible" (Weick 1995, pp. 13–14). Sensemaking is about "authoring as well as interpretation". While interpretation may be more passive and about discovery of meaning, sensemaking is more active and about invention (Weick 1995, p. 8). Sensemaking is "generating" rather than "choosing" an adequate formulation to the raised issue (Weick 1995, p. 9). While the interpretive aspect of the sensemaking process is acknowledged, the making/enacting aspect is central to sensemaking research.

The idea of enacting/making meaning rather than discovering it seems to be well represented in the sensemaking literature, because it is filled with inquiries about how people develop cognitive representations, scripts, or frames to ascribe meaning to organizational phenomena. The strong emphasis on the enacting/making aspect of the sensemaking process has come at the expense of overlooking the discovery aspect, which deserves further research inquiries.

In the following two sections, we synthesize sensemaking studies in the areas of organization research and information technology research. While organization studies examine sensemaking

of organizational stakeholders about organizational phenomena, their major focus is on how stakeholders make sense of organizational change and how doing so facilitates or hinders change. Sensemaking studies in technology research focus on the technological phenomena in two ways: how people make sense of new technology, and how technology may support and facilitate people's sensemaking processes. We discuss the two streams in detail in what follows.

Sensemaking in Organization Research

Organization research is focused on organizing, that is, the processes, structures, and practices of managing social units of people to meet certain goals. Organizing is the social process of achieving goals, and it is always tied to the way people understand their environment; this is why "attentional processes" play a crucial role as a "determinant of human organizing" (Weick 1969, p. 38). The fact that "sense makes organizing possible, and organizing makes sense possible" highlights the sensemaking processes as a crucial component of doing and organizing, because it is the process through which people understand their environment and attach meaning to it (Weick 2000, p. 95). Moreover, sensemaking can have a major impact on organizations (Hahn et al. 2014). For example, Lapointe and Rivard (2005) provide evidence that what people perceive when they start interacting with an electronic medical records system can result in differing technology adoption behaviours, from adoption to passive or aggressive resistance. Such differing adoption behaviours resulted in failure of the implementation project in two hospitals compared to one hospital that successfully delivered the project. In fact, the same software package succeeded in one hospital while failing in another because of the very different perceptions and adaptive behaviours that arose.

Existing research on organizational sensemaking has provided us valuable insights about the various aspects of the phenomenon. To depict the literature on organizational sensemaking, we chose to differentiate four streams of research based on the two main aspects of the sensemaking process. First, sensemaking is always tightly coupled with sensegiving towards others in the organization (Gioia and Chittipeddi 1991); managers and other organizational stakeholders not only make sense of the organizational issues (sensemaking), but they also communicate their crafted meaning to influence others' understanding of those issues (sensegiving) (Bartunek et al. 1999; Gioia and Chittipeddi 1991; Hill and Levenhagen 1995; Maitlis 2005; Rouleau 2005).

While the two processes are closely related, they form two streams of research that deserve to be acknowledged on their own.

Second, people make or give sense either as individuals or collectively in groups. Since organizations comprise collectives that accomplish shared goals, making and giving shared meaning is crucial to organizing activities. In fact, collaborative work is always handled through a common understanding of the process that emerges from and shapes individuals' sensemaking (Gasson 2005). Therefore, here we analytically differentiate the two streams that examine sensemaking at the individual and collective levels, while we acknowledge that the two are empirically interrelated. Table 1-1 demonstrates the four major streams of research that result from the interaction of the two identified aspects of organizational sensemaking; it summarizes what is known in each quadrant. In the following, we discuss each of the four streams in detail. In addition, we will discuss two distinct conceptualizations of sensemaking in the organization research.

Table 1-1. The topics studied in four streams of organizational sensemaking research

	Individual	**Collective**
Sensemaking	The individual, organizational, and network resources on which members and managers draw for individual sensemaking	The dynamics and facilitators of collective sensemaking
Sensegiving	The practices supporting sensegiving to individuals	The dynamics, triggers, enablers, and supporting mechanisms of sensegiving to collectives by managers and other stakeholders

Individual Sensemaking

In any organizational context, individuals need to make sense of what is going on to be able to act accordingly. It is even more important for newcomers who have little information about the

social context of an organization (Louis 1980). Managers also need to make sense of organizational issues by formulating messy issues, facing dilemmas, and handling paradoxes to be able to shape more workable situations (Lüscher and Lewis 2008). There are various resources on which organizational members and managers draw to make appropriate meaning. Here, I identify and represent three contributing sources of sensemaking: individual, organizational, and network resources. Moreover, there are resources specifically available to managers. Table 1-2 details the resources that contribute to individual sensemaking in organizations.

The individual resources consist mainly of the various selves composing the individual identity. Such selves include professional, social-psychological, physiological and financial selves directly affecting how people make individual sense of organizational phenomena (Gephart 1993; Grant et al. 2008). Furthermore, existing knowledge structures and mental maps are the cognitive resources that facilitate the process of sensemaking for organizational members as well as newcomers (Bartunek et al. 1999; Louis 1980). Individual past experiences are well reflected in the existing schemas and shape the individual expectations, and could be consequential for individual sensemaking (Sonenshein 2007). However, the schemas are always under construction and reconstruction to reflect the changes in the context. Additionally, individuals make sense of any organizational phenomenon by drawing on their predispositions and purposes (Louis 1980). What people want to do affects what they attend to and how they perceive the environment. Moreover, the emotions and affective status of individual sensemakers influence how they understand the situation (Bartunek et al. 1999; Gioia and Mehra 1996; Grant et al. 2008; Weick et al. 2005).

Table 1-2. Factors that contribute to individual sensemaking in organizations

Resource types	Contributing factors	References
Individual Resources	• Professional self • Social-psychological self • Physiological self • Financial self • Schema; Predispositions and purposes • Past experiences • Affective status	(Bartunek et al. 1999; Gephart 1993; Gioia and Mehra 1996; Grant et al. 2008; Louis 1980; Sonenshein 2007; Weick 1995; Weick et al. 2005)

Organizational Resources	• Functional integrity • Compliance • Style • Contextual cues • Qualities of organizational culture • Qualities of top management	(Dutton et al. 2002; Gephart 1993; Grant et al. 2008; Harris 1994)
Network Resources	• Network centrality • Proximity to power • Others' interpretations	(Ibarra and Andrews 1993; Lockett et al. 2013; Louis 1980; Sonenshein 2007)
Resources specific to managers	• Awareness of opportunities and threats • Organizational image and identity desired • Organizational strategies • Information processing structures	(Bartunek et al. 1999; Basu and Palazzo 2008; Gioia and Thomas 1996)

The organizational resources are the context-specific factors that contribute to individual sensemaking processes. Among them are functional integrity, compliance, and style (Gephart 1993). Functional integrity refers to the main purpose of the organization that needs to be met for the organization to survive. That is the function for which the organization is designed and developed, it is core to the organizational identity, and it strongly affects how individuals make sense of the organization. Compliance refers to the rules and standards requiring conformity and compliance of the individual members; it includes the policies, hierarchies, and job descriptions. The style resource of an organization refers to the informal norms that define the range of acceptable behaviours and activities in the organization. Moreover, an organizational strategy could affect how individuals make sense of new phenomena, especially in a crisis (Bundy and Pfarrer 2015).

In addition, there are various contextual cues that are the raw ingredients of sensemaking processes. In an organizational context, such cues may include demographic patterns, qualities of organizational culture, and qualities of top management (Dutton et al. 2002). These cues would affect individuals' sensemaking and action in the workplace. For instance, whether to raise an issue related to gender equality in the workplace could be dependent on such cues in connection with demographics and top management.

Organizational culture influences the individual sensemaking by shaping the content of individual cognitive schema; that is, the common culture of the organization promotes the

congruence of many individual sensemakings within an organization (Bean and Eisenberg 2006; Harris 1994). Although culture is a collective-level concept, it is carried by every individual within that culture and thus can affect the way the individual makes sense of many organizational phenomena. For instance, an organizational culture of voluntarily trying to help each other may influence individuals' sensemaking about the organization (Grant et al. 2008). In addition to shaping the schema, culture can influence sensemaking through the choice of which salient schema to activate. From this point of view, the selection phase of the individual sensemaking process is affected by cultural norms and values. The effect of culture is most salient in international and multicultural organizational environments where people of various cultures organize and work together (Shoib and Nandhakumar 2003). In such a context, bridging cultural frames is needed to facilitate sensemaking (Su 2015).

The network resources refer to the aspects of the individual's social network that contribute to their sensemaking. Since sensemaking is a social process, particularly in organizations (Weick 1995), other people's schema and interpretations would be as important as the individual's interpretive schema in the process of sensemaking (Louis 1980; Sonenshein 2007). Change agents in organizations draw on this social aspect of sensemaking to influence how people interpret change and act accordingly. Moreover, the individuals' positions within their social networks may influence sensemaking (Lockett et al. 2013). Individuals' sensemaking would also be affected by the stakeholders with whom they interact in the organization (Songqi Liu et al. 2015). Network centrality and proximity to power positions are among such position-related features (Ibarra and Andrews 1993). The more central individuals are to the network (i.e. the more important they are to the network) and the less distant from the power position (i.e. having more interaction with people with higher social power who give them access to resources), the more their sensemaking is affected by their social network.

Furthermore, there are resources specifically available to managers and leaders that make sense of organizational phenomena. Strategic awareness of opportunities and threats influences how top managers understand and attach meaning to strategic change initiatives (Bartunek et al. 1999). To successfully accomplish strategic change in organizations, top management has to modify the organizational image and identity to reflect the new strategic position. Therefore, managers' sensemaking of strategic issues during a strategic change is more affected by the

desired image and identity than by the current ones (Basu and Palazzo 2008; Gioia and Thomas 1996). In other words, during strategic change, whether executives label a specific issue as a threat or an opportunity and as strategic or tactical depends on the desired identity and image of organization. Moreover, the strategies and information processing structure seem to influence top management's sensemaking of organizational issues. Regarding the information processing structure of top managers, the more participative, interaction-intensive and informal the structure is, the more information processing capacity it provides and the more strategic will be the interpretation of the issues. Regarding the strategy, the more offensive the organizational strategy is, the more strategic will top management's interpretation of the issues be (Gioia and Thomas 1996).

Sensegiving to Individuals

Leaders and other organizational stakeholders consistently engage in sensegiving to other individuals, because sensegiving is tightly linked to managing change in organizations. For leaders, initiating strategic change processes involves a sequence of sensemaking and sensegiving activities. It involves the four phases of envisioning, signalling, re-visioning, and energizing that consist respectively of sensemaking and sensegiving and sensemaking and sensegiving activities (Gioia and Chittipeddi 1991). While sensemaking is about understanding, sensegiving is about influencing. While sensemaking is mostly cognition-based, sensegiving is mostly action-based.

In fact, sensegiving is tied to sensemaking in such a way that it is sometimes hard to differentiate the two in organizational processes. However, the proportion of the two would vary across different phases of organizational change (Gioia et al. 1994). In the early stages, the change agent or top management is mostly engaged in making sense of the organizational situation retrospectively and creating plans prospectively. Later, the change agent more and more engages in sensegiving processes that influence how organizational stakeholders understand and conform to the changes. Moreover, both the sensegiving and sensemaking activities are based on symbols and symbolic actions that support representation and communication of meaning (Gioia et al. 1994).

The meanings that leaders try to communicate are not necessarily equivalent to the ones that people receive, thus the sensegiving activities are not always successful. Such failure may happen because the continuously changing sensemaking of the leader can result in inconsistent sensegiving (Bartunek et al. 1999).

Across organization research, sensegiving has infrequently been examined at the individual level. This is generally due to the fact that sensegiving is mostly employed by top managers whose audience normally comprises collectives rather than individuals. However, the conceptual difference between sensegiving by individuals versus sensegiving by collectives deserves to be more thoroughly appreciated and calls for further research.

Middle managers are most of the time in the front line of changes, as they are the ones who are supposed to communicate the meaning of the changes to lower-level employees and external clients. They may employ various practices to communicate the appropriate sense to individual clients. Such practices include translation of the new orientation, overcoding the new strategy, disciplining the client, and justifying the change (Rouleau 2005). Translation is authoring the new meaning and telling the new story by choosing the symbolic elements and relating them to make the story; the symbols should belong to the language of the client to be able to transmit the message. Overcoding inscribes words and actions around the new strategy using the socio-cultural codes, norms and symbols of the context, that is, materializing the story in this way. Disciplining is to convince the client to support the story and act accordingly. Justifying is to provide good reasons, based on the client's discourse, that support the change and the story provided.

In summary, individuals in organizations are continuously engaged in sensemaking and sensegiving processes that unfold sequentially and simultaneously. The processes feed each other and have their own specific antecedents. Sensemaking is mostly cognition-oriented, while sensegiving is action-oriented. There are multiple resources that feed the cognitive sensemaking processes and multiple practices that support the active sensegiving activities. Figure 1-2 summarizes the resources and practices that support sensemaking and sensegiving processes at the individual level in organizations.

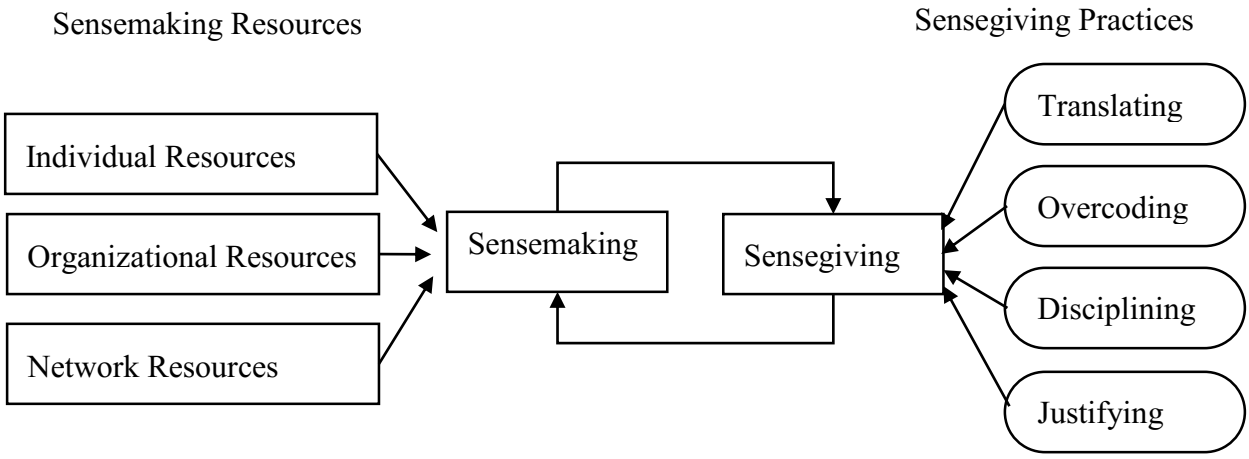

Figure 1-2. Individual sensemaking and sensegiving

Collective Sensemaking

Collective sensemaking is about how groups of people arrive at a shared sense about a new experience in the organization. It arises from the need in an organization to have a "collective mind" and shared understanding about issues; it is even more important when the collective is dispersed across time and space (Campagnolo et al. 2015). Collective sensemaking affects how people create and execute organizational strategies in relation to environmental changes (Lewis et al. 2011). It refers to the process of collectively making sense of an interruption or surprise. Since collective sensemaking occurs through social interaction within the group, the social component is of higher importance than the cognitive one. Past research sheds light on the dynamics of collective sensemaking and the factors that facilitate the process, as depicted in Table 1-3.

Dynamics of Collective Sensemaking

The dynamics cannot be understood apart from like-minded organizational clusters. Organizational members normally form clusters within which they have similar understandings of phenomena. In this sense, organizational members may not generate, but rather choose one of the competing meanings available; and their choices would be affected by their contexts, including their roles in the organization (Henfridsson 2000; Rose and Kræmmergaard 2006; Vaast 2007). For instance, the cluster of technical employees and the cluster of top managers most likely make different collective minds about project success factors. While technical

employees assume experimentation and technical creativity are the core to project success, managers may envision administrative creativity and project management as the major success factors (Drazin et al. 1999). However, there is always a balance between the multiple understandings of these clusters, and the balance can change during team work through a process of negotiation (Kjærgaard et al. 2010). Negotiation of the balance unfolds through articulation and elaboration processes in which people use material practices, verbal articulation and interactive talks to translate the dispersed individual meanings to shared collective meaning (Ovaska and Stapleton 2010; Stigliani and Ravasi 2012). Moreover, the specific nature of an issue may influence the balance. When there is a functionality crisis, the balance of the collective sensemaking may change to favour the understanding of the technical staff who are capable of resolving the crisis. When there is a managerial crisis, like cost or schedule issues, the disruption may change the collective sensemaking to favour the understanding of project managers, who are capable of dealing with such issues (Drazin et al. 1999).

Table 1-3. The dynamics and facilitators of collective sensemaking

Aspects of collective sensemaking	Findings	References
Dynamics	• The collective mind is a balance between role-based like-minded clusters • The balance may change according to the nature of disruption or crisis • The type of balance formulates forms of collective sensemaking that results in different accounts and actions	(Balogun and Johnson 2004; Drazin et al. 1999; Kjærgaard et al. 2010; Maitlis 2005)
Facilitators	• Group goals, identity, and legitimacy • Culture and shared history • Heedful interrelating • Formal organizational schema • Social norms • Responsibility assignment • Specific practices	(Bartunek et al. 1999; Basu and Palazzo 2008; Gasson 2005; Harris 1994; Maitlis 2005; Wahlström et al. 2011; Weick and Roberts 1993)

Even if there is a unique meaning shared across the whole organization about a specific issue, sudden changes may unsettle the situation in such a way that the current schema and sensemaking can no longer handle the work. Such changes may be forced by the top

management or the outside environment. Then like-minded groups start to develop clusters of schema. These clusters of schema come closer together later, during the processes of coordination and negotiation between the groups at stake. Eventually, shared but differentiated schema will form that are characterized by contractual intergroup working (Balogun and Johnson 2004). Moreover, the group identity and legitimacy among the stakeholders are two forces that shape the meaning made within the collectives. Groups tend to make the meaning that is consistent with their shared identity and looks legitimate to all stakeholders (Basu and Palazzo 2008).

The social process of collective sensemaking is another component of its dynamics in organizations. It is a departure from the cognitive approach of examining how organizational members interact to collectively make meaning about their environment and facilitate collective action. The more sensegiving there is by leaders, the more controlled the sensemaking process is; and the more sensegiving there is by the stakeholders, the more animated the process is (Maitlis 2005). The combination of these two aspects creates the four different forms of sensemaking processes. Each of the four forms results in shaping distinct accounts and actions including unitary/multiple accounts, narrow/rich accounts, one-time/emergent series of action, and consistent/inconsistent action.

Facilitators of Collective Sensemaking

Agreement and congruence of individual minds and schema is the core to successful collective sensemaking. Such agreement and development of a collective mind occurs through heedful interrelating, responsibility assignment, formal organizational schema and social norms (Maitlis 2005; Weick and Roberts 1993). Having common goals and sharing tacit knowledge, expertise and practices also facilitate creating a collective mind (Gasson 2005; Hartnett et al. 2012). Moreover, the history of previous organizational changes influences how people and managers make sense of the change being undergone (Bartunek et al. 1999). Thus, collective sensemaking would be facilitated by having shared experience and background about the issue.

Collective sensemaking is also affected by organizational culture. Since culture carries the meaning, norms, and values shared across the organization's members, it affects the individual cognitive schema to shape them in similar ways and make collective sense of many

organizational phenomena (Harris 1994). Accordingly, it would be more difficult for people from different cultures to make collective sense. Besides, creating a collective mind and acting on the basis of culturally shared schema would also reinforce the cultural norms and values of an organization.

The collective mind is affected by and manifested in the actions of individuals. "Heedful interrelating" refers to the members of the collective interacting with each other with awareness about how their actions are related (Weick and Roberts 1993). It facilitates the creation of the collective mind and would be disrupted if the collective mind were dissolved.

Crisis management teams are interesting subjects of study for the process of collective sensemaking. Investigating collective sensemaking in control rooms, Wahlström et al. (2011) studied how experts from various fields came to a shared understanding to resolve a safety-critical incident. They identified three types of practices that facilitate the sensemaking process: practices for using redundant representations, updating inter-subjective understanding by verbal coordination, and gradually correcting hypotheses to match actions.

Sensegiving to Collectives

Sensegiving to collectives is about leaders or other organizational stakeholders giving a shared sense to a group of people as a collective. The meaning people make is fundamental to the process of organizing, so one major day-to-day activity of leaders is to communicate the appropriate meaning to the organizational members and stakeholders (Gioia and Chittipeddi 1991). Leaders usually have to communicate the plans and changes to a collective audience rather than just individuals. Therefore, the sensegiving process in organizations is examined mostly in its collective form. However, sensegiving in organizations is not limited to leaders and top managers, but it extends to all other stakeholders (Maitlis and Lawrence 2007). In this section, we examine the factors that trigger and enable sensegiving activities by leaders and other stakeholders and the practices employed to communicate the collective meaning, as depicted in Table 1-4. Although some of the sensegiving practices provided are more useful to top managers and leaders, there is no reason to believe that such practices would be different for other stakeholders.

There are various factors that trigger and enable sensegiving activities, and these seem to be different for leaders and other stakeholders (Maitlis and Lawrence 2007). *Trigger* factors are those that initiate the process of sensegiving. Leaders are triggered to undertake sensegiving by the ambiguity of an issue. However, the other stakeholders would be motivated to engage in sensegiving activities when they perceive an issue to be significantly consequential to them or to the entire organization, and also perceive the leader as being incompetent to handle the issue.

Table 1-4. Mechanisms for sensegiving to collectives

Aspects of collective sensegiving	Managers as sensegivers	Other stakeholders as sensegivers	References
Triggers	• Ambiguity of an issue	• Issue is significantly consequential to them or to the organization	(Maitlis and Lawrence 2007)
Enablers	• Issue-domain expertise • Organization performing strongly in that issue domain	• Issue-domain expertise • Issue-domain legitimacy • Organizational routines that support them	(Maitlis and Lawrence 2007; Petkova et al. 2013)
Practices	• Storytelling practices o Making issue appear logical and reasonable o Providing a credible story o Making issue consistent with values of the receivers o Demonstrating the credibility of the sensegiver o Managing impressions o Using metaphors • Managerial practices o Developing and exploiting key relationships o Managing information o Protecting and exerting formal authority o Using sanctions and rewards		(Bartunek et al. 1999; Brown et al. 2008; Fiss and Zajac 2006; Hill and Levenhagen 1995; Maitlis 2004)

The *enablers* of collective sensegiving are the factors that empower the leaders or other stakeholders to perform effective sensegiving activities. Organizational top management can be effective in sensegiving when they have expertise in the specific issue and the organization performs strongly in that domain (Maitlis and Lawrence 2007). Moreover, the human capital of the executives boosts the intensity and effectiveness of their sensegiving (Petkova et al. 2013). Other organizational stakeholders are effective in sensegiving activities when they have expertise and legitimacy in the issue and are supported by the organizational routines and processes (Maitlis and Lawrence 2007).

There are several *practices* employed by managers and stakeholders to give appropriate sense to collective others. I divide these practices into two groups, storytelling and managerial practices. While managerial practices are specific to managers, storytelling practices could be used by other stakeholders, too. To facilitate the communication of appropriate meaning to collectives, first of all, one always need to draft and tell the story in an appropriate and effective way. This includes providing the phenomenon with a credible story that appears logical and reasonable to all stakeholders to be able to obtain their support. The sensegiver should frame the change in a way that makes sense to the varied stakeholders of the organization. Such a "framing" strategy is core to the sensegiving process as well as to the success of the strategic change initiatives (Bartunek et al. 1999; Fiss and Zajac 2006). The choice of the appropriate framing would depend on structural determinants such as the dependence and power of each stakeholder. The final framing of the change initiative would be a negotiated outcome influenced by the significant stakeholder groups. Moreover, the chosen framing should be made consistent with the norms and values of the receivers.

To effectively communicate the appropriate meaning, the storyteller needs to demonstrate her or his credibility. This may include engaging in impression management practices to display an image of legitimacy and competence; it could influence the perception of group members towards the individual sensegiver (Brown et al. 2008; Maitlis 2004). Moreover, using metaphors can be useful in the process of effective communication of meaning and stories, especially for radical change and entrepreneurial organizations. A metaphor is more abstract than a mental model; it is incomplete and somewhat paradoxical (Hill and Levenhagen 1995). Such incompleteness allows for flexibility in communication and modification of meaning and story;

this flexibility is much needed in sensegiving in situations of radical change. Moreover, metaphors incorporate emotion as well as cognition. They are capable of not only communicating meaning to a collective, but also motivating the collective towards action.

There are managerial practices that leaders and managers may use to communicate the meaning needed. These practices normally draw on a number of organizational features to communicate and give the appropriate meaning. Such features include organizational structures, rules, events, formal statements, physical designs and discourses (Bartunek et al. 1999). These are the features available to managers to manipulate and communicate the meaning they intend to give, especially when they need to reach a collective of members. Such practices include developing and exploiting key relationships with influential board members. Leaders may also manage information by gathering, holding, concealing and disseminating appropriate information to certain key people at the right time. Moreover, protecting and exerting formal authority given by their position while behaving humbly could facilitate communication of meaning to collectives; this could include using formal sanctions and rewards (Maitlis 2004).

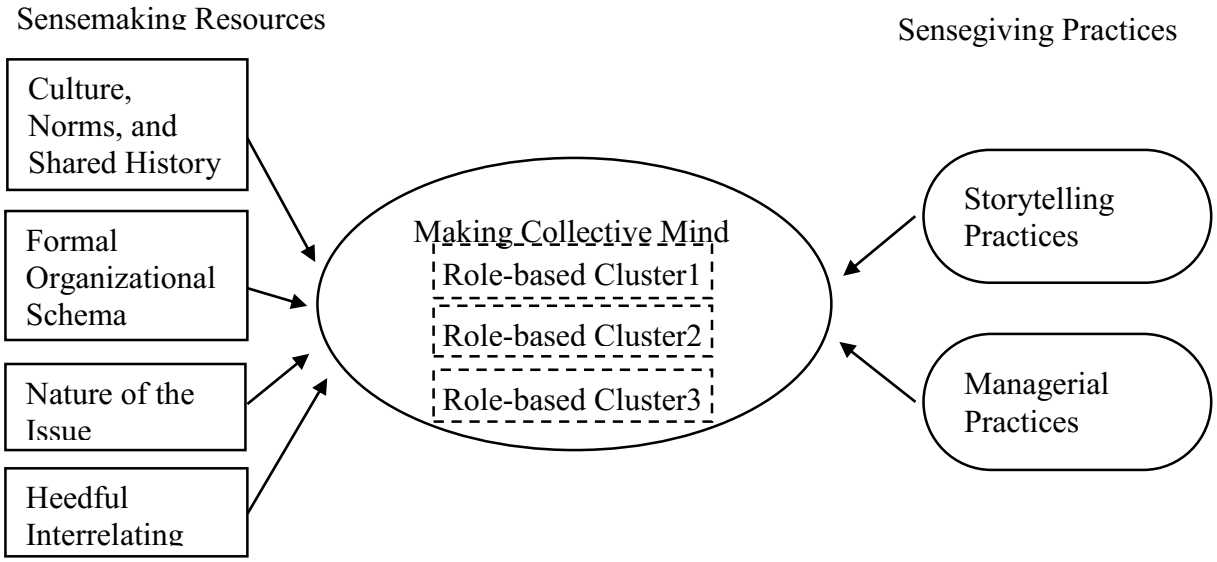

Figure 1-3: Collective sensemaking and sensegiving

In summary, sensemaking and sensegiving at the collective level are about shaping a collective mind. While there are always numerous like-minded clusters in an organization, the balance between the existing clusters, which are mostly role-based, could define the creation of the

collective mind. Collectives draw on varied sources to make sense of organizational changes. Moreover, managers employ various storytelling and managerial practices to communicate the intended meaning to collectives of organizational members and stakeholders. Figure 1-3 summarizes the sources and practices used to shape and influence the collective mind.

Sensemaking Conceptualization and Operationalization

Reviewing the four streams of sensemaking studies in organization research, we have found that the meaning that people make and communicate through sensemaking and sensegiving processes is conceptualized in two fundamentally different ways and operationalized accordingly: schema and narratives, each of which is further discussed in the following. It is notable that the dominant interpretivist approach to sensemaking research has required qualitative research methods as the main mode of inquiry; quantitative methods are sometimes used to complement the qualitative ones (Gioia and Thomas 1996), but we do not know of any exclusively quantitative inquiry.

Meaning as Cognitive Schema

From the cognitive perspective, schema are the building-blocks of human perception. They are dynamic cognitive structures that store an individual's knowledge regarding concepts, events, and entities (Harris 1994). They form a cognitive map that encodes the flux of incoming information and decodes the individual experiences to be understood. This map guides human perception and interpretations about the past, the present and the expectations of the future. Organization-related individual schema may be related to the self, other persons, the organization, objects/concepts, or events; they may cover the full range of meaning an individual may make in an organization.

A schema or mental model may evolve through time from intuition to metaphor and then to formal model (Hill and Levenhagen 1995). While intuition is unconsciously perceived, open-ended, and incorporates felt beliefs that cannot be verbally articulated, a metaphor is an incomplete and abstract mental model that can be elaborated and articulated. A metaphor can evolve into a formal model when it is more precise and develops more details.

Schema are operationalized as categories of meaning that are used to label parts of human experience. Since they are context-specific, such categories are extracted qualitatively from data

and identified according to the specific case of a study. However, the extent of each meaning can be later measured quantitatively using survey items (Gioia and Thomas 1996).

The qualitative extraction of the schema can be done using open-ended coding of interview data of individual perceivers. Categorical analysis is useful for grouping open-coded data into categories of schema (Gioia et al. 1994; Gioia and Thomas 1996). In this method, all the first-order terms and concepts repeatedly used are extracted and then grouped into meaningful second-order categories that in turn can be grouped into higher order categories. Gestalt analysis can also be used for identification of such higher order categories. In this way, the major meanings emerge inductively from the qualitative data.

Meaning as Narratives

From another point of view, narratives or stories are the building-blocks of human understanding; people understand their experiences and organize them through stories that make their experiences meaningful to them (Polkinghorne 1988). Proponents of this view define the organization as a network of meaning, and highlight the organizing role of narratives by asserting that "narratives provide members with accounts of the process of organizing" (Mumby 1987, p. 113). Some even go further to say that "the basic technology of organization … is a technology of narrative" (March 1996, p. 286). Pentland (1999) identifies four levels of structure in narratives: text, story, fabula, and generating mechanisms. While fabula is the generic description of a sequence of events, story is a version of the fabula from one's point of view, and the text is a telling of that story with a unique narrative. Generative mechanisms, as Pentland (1999) suggests, are the underlying structures supporting or restricting the fabula.

From this perspective, sensemaking is the process of narrativization or narrative-making (Brown et al. 2008). This view is consistent with Weick's (1995) question, "How can I know what I think until I hear what I say?" In other words, making sense is the process of retrospectively making stories that help us to understand our experiences. Analyzing narratives, Weaver et al. (2010) identified the three narratives older people use to justify their non-use of new technology. Brown et al. (2008) examined sensemaking in teams and how people make a collective story of what is going on with the team. Such stories are differentiated from each other in ways that reflect the roles that the sensemakers play in a team. People rely on collectively constructed stories to

understand ambiguous situations (Bird 2007). Narratives can create technological discourses that co-exist and compete to form the dominant sensemaking in groups (Rose and Kræmmergaard 2006).

Narratives can be seen as the building-blocks of not only the sensemaking process, but also the sensegiving process. To give the appropriate sense of strategic changes, managers communicate success stories and stories of progress (Snell 2002). Narrative-based conceptualization of meaning allows for focusing on the type of stories people share and on how they are communicated (Brown 2000; Dunford and Jones 2000).

To operationalize the narratives, various types of discourse analysis methods are useful (Brown 2000). Gephart (1993) proposed one such method that analyzes sensemaking stories as textual data and captures the practices, resources and processes of sensemaking and sensegiving. His proposed method includes theoretical sampling, computer-aided qualitative data analysis, and expansion analysis. Theoretical sampling develops a theoretically meaningful sample of the textual data to be analysed in detail. The computer-aided analysis, like index generation and key word lists, supports the development of the theoretical sample. Such analysis involves breaking down the text and identifying the main parts that reveal significant themes. The expansion analysis is the process of conceptually interpreting the hidden meanings and themes of the theoretical sample of the text.

Furthermore, argumentation analysis could be employed for analyzing the narratives. Berente et al. (2011) analyzed the claims that managers make and the arguments they provide to support those claims about how a virtual world can create value for organizations; such claims and argumentations are seen to be the meaning that people make of the phenomenon.

As a qualitative research method, nominal group technique is also employed to extract the meaning people can make about a phenomenon while interacting with each other (Reyes and Kheng 2015). Boland (1984) gathered a group of managers in a nominal group to exchange ideas and collectively make stories about accounting data of an organization. This technique is able to account for the interactions unfolding within the process of making stories collectively; thus it is useful for examining the process of collective sensemaking.

In comparison to the schema-based cognitive understanding of the meaning people make, narrative conceptualization is better able to capture the social and contextual, and perhaps richer, aspects of meaning, because it appreciates the symbolic elements of sensemaking and how symbols represent and communicate meaning (Rouleau 2005).

Sensemaking in Technology Research

Information systems and their combination with organizational features and practices are changing the way organizing unfolds by providing new capabilities and affordances that support new forms of coordinating work (Zammuto et al. 2007). This has evolved technology into an essential part of every organizational phenomenon and has led organizational scholars to study technology sensemaking in order to understand how technology is enacted and woven into the organizational fabric. Technology research, as we discuss here, refers to the field focused on the processes and practices of developing, implementing and using information technologies in organizations.

Here, we identify and present two major streams of sensemaking research related to technology. The first examines how information and communication technologies are designed and employed in organizational contexts to facilitate and support individual and collective sensemaking about organizational issues. This is what we call "sensemaking *through* technology." The second stream inquires about how people understand and make sense of new technologies in organizations. This is what we call "sensemaking *about* technology." The two streams are elaborated and discussed in what follows.

Sensemaking through Technology

Communication technologies can support people both as they seek information and as they make and communicate meaning about organizational phenomena as individuals and collectives (Jang et al. 2015). Systems that support sensemaking and the interpretive processes of organizational stakeholders can boost performance (Im and Rai 2014; van Oorschot 2014). Investigating sensemaking through a web-based messaging system in a hospital setting, Yang et al. (2013) demonstrated that sense-giving, sense-demanding, and sense-breaking practices were respectively the most frequent practices in the messaging system.

This stream of research is mainly occupied by Human-Computer Interaction (HCI) studies that examine how information and communication technologies affect the process and products of sensemaking in organizations and suggest design principles needed for a technology to support individual and collective sensemaking (Pirolli and Russell 2011). Indeed, this is not about making sense of technology, but making sense through technology. Here, we differentiate and represent the design principles and requirements needed for systems that support individual and collaborative sensemaking, as depicted in Table 1-5.

Table 1-5. Requirements of systems that support individual and collaborative sensemaking

Support systems	Sensemaking System Requirements	References
Individual Sensemaking Support Systems	• Providing visual representations • Facilitating reflection and deliberation • Finding and annotating relevant information • Supporting problem decomposition • Dynamically associating related information • Fluid Interactions with information • Linking schema elements to evidence • Filtering schema in varied aspects • Viewing schema at different levels of analysis	(Attfield and Blandford 2011; Baker et al. 2009; Butcher and Sumner 2011; Paul 2006; Seidel et al. 2013)
Collaborative Sensemaking Support Systems	• Extracting and transmitting complex contextual cues • Facilitating necessary social processes • Enabling communication of emotions and feelings • Supporting identity construction and self-presentation • Visualizing and sharing sensemaking trajectories • Supporting action and activity awareness by notification and timeline visualizations	(Paul 2006; Paul and Morris 2011; Paul and Reddy 2010)

Individual Sensemaking Support Systems

Technologies that support sensemaking by individuals are focused on facilitating cognitive processes of sensemaking such as construction and maintenance of cognitive schema. An effective support system should help sensemakers find new information, make sense of it using their representations, and encode new knowledge into modified representations (Butcher and Sumner 2011). To facilitate individual sensemaking, visual representations need to support the four basic visual perception approaches of association, differentiation, ordered perception, and

quantitative perception. Moreover, they need to support gestalt qualities and analogical reasoning and to be consistent with the sensemaker's stored knowledge (Baker et al. 2009).

Since sensemaking is generally a retrospective process, the system needs to facilitate reflection and deliberation on existing information and past actions (Paul 2006). In addition, it would support prospective sensemaking by letting the user deliberate and assess the information about alternative future actions (Seidel et al. 2013). In making sense of textual information, there is a need to find the relevant information and mark it to be able to return for reflection and deliberation. Annotation capabilities of the system enable people to efficiently search and mark the relevant information (Attfield and Blandford 2011). In addition, being able to interact more fluidly with the pieces of information enhances the capacity to identify the relevant parts of the information needed; this may be done through the cross-referencing capabilities of the system. Moreover, the system can ease retrospection by structuring the issue and the process of sensemaking into steps to be followed by the individual sensemaker (Paul 2006).

The system capability for problem decomposition is very useful for simplifying the issue at hand and making the appropriate schema to explain the issue. Moreover, systems that support linking and associating relevant parts of information could ease the process of making representational categories and schema. Schema construction processes could be further facilitated by enabling individuals to associate each part of the schema with its related evidence and information (Attfield and Blandford 2011). This allows for continuous reflection of new information into schema and appropriate maintenance and modification.

To manage extensive schema, people need the capability to filter them according to different aspects to attain various insights about an issue. Systems may provide the opportunity to assess schema at different levels of analysis. Higher level schema represent the big picture and the general story, while the lower level schema explain the story in detail (Attfield and Blandford 2011). Moreover, systems can support the collection of rich information as the basis for information exploration and insight building (Gersh et al. 2006).

Collaborative Sensemaking Support Systems

Research on technologies that support collaborative sensemaking is highly focused on facilitating the social processes of collective sensemaking. During the Egyptian Revolution and

Arab Spring in 2011, Twitter proved to be an exemplary tool for people to make collective sense of the situation and manage social change through collecting information and maintaining situational awareness using hashtags (Onook Oh et al. 2015). Systems that support sensemaking in collocated or distributed teams have to facilitate the extensive social process of sensemaking in every aspect from extracting relevant cues to constructing and maintaining schema and identities.

To support collaborative sensemaking, systems should enable people to extract and transmit complex contextual cues within the collective. This is especially essential when the team is not collocated and does not share the same social and physical context. Since contextual cues are the basis for individual sensemaking (Weick 1995), it is hard for collectives to make shared sense of any phenomenon with disparate and poor cues.

Collectives develop shared understanding through social interaction and communication (Maitlis 2005). To successfully conduct sensemaking processes, a system needs to support necessary social processes. For instance, trustworthiness is the basis of most social interactions, and any support system needs to establish and demonstrate the trustworthiness of each party (Paul 2006). This is particularly vital for groups of people with limited shared history.

Sensemaking is not just about cognition and mental models; it also involves individual emotions at the moment of making sense (Gioia and Mehra 1996; Weick et al. 2005). Support systems need to enable communication of emotions and feelings to allow effective sensemaking (Paul 2006).

Identity construction is at the core of the sensemaking behaviour (Weick 1995), and so support systems would be much more effective if they could facilitate identity construction and maintenance activities of individuals in the community. If supported by the technology, self-presentation behaviours would give people the opportunity to build and represent their own preferred selves in the community (Paul 2006).

Understanding how the other members of a collective make sense of a situation, the steps they take, and the trajectories they follow would facilitate shared sensemaking in the group. Visualizing and sharing sensemaking trajectories by support systems could facilitate sensemaking through information technologies (Paul and Reddy 2010). Using these technologies

not only coordinates the meaning that group members share about a specific phenomenon, but also helps people to make consistent meaning about the same phenomenon over time. Moreover, collective sensemaking technologies need to recognize the difference in user roles and provide a role-based multi-view design (Wu et al. 2013).

Other than knowing the trajectories, seeing the big picture of what others are doing, their actions and their activities strongly informs the sensemaking of group members. Effective support systems should enable action and activity awareness to facilitate collaborative sensemaking (Paul and Morris 2011). Posting notifications about others' actions and visualizing activity timelines are useful strategies to raise action and activity awareness. Moreover, sharing know-where and know-what information has been proven to facilitate shared sensemaking in the emergency incident management context (Landgren 2005).

Sensemaking about Technology

After reviewing research on sensemaking *through* technology, now we turn to examining sensemaking *about* technology. While the former section examined how technology facilitates individual and collective sensemaking, this section investigates how individuals make sense about the technology itself. Technology is a substantial organizational phenomenon, so it is always subject to sensemaking. It is recognized as being equivocal, admitting "several possible or plausible interpretations" (Weick 1990, p. 2). Technology is an equivocal reality understood in very different ways by various people in diverse contexts, and this makes it necessary for individuals and collectives to make sense of technology before acting on it. Users' sensemaking of new technology affects their practices and how they adapt it to their work routines (Ellway and Walsham 2015; Yu Tong et al. 2015). For instance, users who alternatively understood a healthcare system as facilitator, inhibitor, guardian angel, or imposer used the system at different levels and in various ways, then came up with very different results on how to successfully control their asthma (Savoli and Barki 2013). Technology sensemaking research delves into three aspects of the phenomenon in organizations: cognitive processes, social context and sensegiving activities, which are examined below.

Cognitive Processes

The first and foremost aspect of technology sensemaking arises from recognition of technology as "*équivoque*" (Weick 1990, p. 2); multiple interpretations of the technology highlight the role that individual cognitive processes may play. Scripts (Weick 1990), technological frames (Orlikowski and Gash 1994), and social representations (Vaast and Walsham 2005) are the mental models constructed and maintained by individuals to guide their behaviour towards technologies. These are all cognitive structures that link technology to individual actions. Technology affects individual action by promoting technology-enabled actions and embedding them into individual cognitive structures. Moreover, actions structure the use of technology by reinforcing or modifying specific mental models.

However, these various mental models are not identical. While a script is the general mental model that refers to the sequence of actions that make up an event (Weick 1990), a technological frame is the cognitive structure concerning the assumptions, expectations, and knowledge that people use to understand and interpret technology in organizations. Technological frames concern not only the nature and role of the technology, but also its application in specific contexts (Orlikowski and Gash 1994). Like a script, a social representation is more general than a technological frame; it is not limited to technology, though it affects people's understanding of the technology. That is, what affects individual understanding of the technology is not limited to a person's assumptions about the technology per se, but also includes more general assumptions related to the whole social system. However, unlike a script or a technological frame, a representation is a collective-level mental model shared among members of the community, rather than made and maintained at the individual level (Vaast and Walsham 2005).

Whereas congruence of the individual mental models facilitates technology implementation in organizations, their incongruence may potentially either raise conflict and difficulty (Azad and Faraj 2008; Olesen 2014) or productively improve the system if treated wisely (Karsten and Laine 2007). Executives create and carry dominant frames that may be influential over and above others over time (Olesen 2014). They can play a major role in making consensus among frames by promoting IT, engaging users with IT, and facilitating communication between IT and business people (Tallon 2014). Mental models can play both facilitating and constraining roles. They facilitate action by providing the cognitive structure and assumptions for understanding the

world, and they constrain creative action by compelling people to distort information to comply with existing frames (Orlikowski and Gash 1994). Various aspects of the cognitive processes have been examined, including frame domain categories, frame patterns, framing processes, and triggers. These aspects are depicted in Table 1-6 and further presented in the following.

Domain categories: Technology-related mental models or technological frames are related to various domain categories. They can represent individual understanding about IT features and attributes, IT organizational applications, incorporating IT into work practices, and developing IT applications in organizations (Davidson 2006). Executives make their own frames about the application and impact of IT in their organizations (Tallon and Kraemer 2007). Although the contents of frames are highly varied and context dependent, they mostly refer to one of the categories of frame domains. There are also technology-specific categories of frame content. For instance, frames related to GPS technology for taxi drivers may consider GPS technology as detector, navigator, explorer, or guardian; each refers to one aspect of the technology's application (Hou 2008; Hsiao et al. 2008). The structure of a frame is at least as important as its content. Various aspects of frame structure include construction of arguments, the breadth of issues considered, and the rigidity of frames. Both the content and the structure of frames need to be taken in account when identifying and examining technology frames (Davidson 2006).

Patterns: Three patterns of technology sensemaking have been identified: pragmatic, romantic, and pessimistic symbolism (Prasad 1993). Pragmatic sensemaking understands technology as efficient, inevitable, and linked to organizational survival. Whereas pessimistic sensemaking of technology relates it to negative consequences like errors, physical hazards, and misuses, romantic sensemaking interprets technology in positive ways related to playfulness, fun, and intelligence. These three patterns occupy different proportions of technology sensemaking during various phases of technology use in organizations from training to technology routinization.

Table 1-6. The cognitive aspect of technology sensemaking

Framing aspects	Findings	References
Domain categories of frames	• IT features and attributes • IT organizational applications • Incorporating IT into work practices • Developing IT applications	(Davidson 2006; Orlikowski and Gash 1994)

Patterns of frames	• Pragmatic • Romantic • Pessimistic symbolism	(Prasad 1993)

Processes of framing	• Individual level processes
	  o Initial adoption
	  o Transitional adoption
	  o Senselessness in post-adoption
	• Collective level processes
	  o Frame differentiation
	  o Frame adaptation
	  o Frame stabilization
		(Azad and Faraj 2008; Hsiao et al. 2008; Jensen and Kjærgaard 2010)

Triggers	• Situational factors
	  o Novelty of the technology
	  o Discrepancy between observation and expectation
	  o Deliberative initiatives
	• Technological factors
	  o Core vs. tangential
	  o Concrete vs. abstract
		(Griffith 1999; Hsiao et al. 2008)

Framing processes: Focusing on the framing processes rather than on the frames themselves enriches the understanding of the dynamics of technology sensemaking processes (Davidson 2006). Individuals and collectives go through different processes of technology sensemaking. While individual technology sensemaking is about making and maintaining frames, collective sensemaking is about making the diverse frames of individuals more congruent and less disparate. To make sense of technology, individual sensemakers go through the three phases of initial adoption, transitional adoption, and senselessness in post-adoption (Hsiao et al. 2008). The initial adoption phase makes technology sensible to users and establishes the new meaning. Transitional adoption adjusts and reinforces the new practices and routines, and post-adoption institutionalizes enacted technology-in-use. While the process starts with consciously making sense about the new technology itself and making sense of how to use it, it continues to a state of senselessness in which the individual automatically follows the meanings and mental models already made. Digging into the transitional phase of sensemaking processes, Zamani et al. (2013) explained how iPad users elaborate their initial frames, question the frames, compare, preserve, and reframe them. Consequently, users may change either their frames or the technology at hand by developing workarounds; otherwise, they may abandon the technology. During the

transitional phase, professional identity plays a key role in shaping the meaning people attach to technology. People tend to construct meaning that is more consistent with their professional identity and practices (Jensen and Kjærgaard 2010; Svejvig and Jensen 2013).

To collectively make sense of technology, groups of organizational stakeholders go through frame evolution processes in the three general phases of frame differentiation, frame adaptation, and frame stabilization that reconcile the competing frames into a truce frame (Azad and Faraj 2008). A truce frame is a stable frame on which the competing parties agree. Frame differentiation is the process through which multiple frames interact with each other and set opposing frames. Such opposing frames start to get modified towards a truce frame during frame adaptation processes. Negotiation between stakeholder frames, the balance of power between negotiating parties, and each party's stakes determine the proportional reflection of competing frames into the truce frame. During frame stabilization processes, there is agreement on major aspects of the truce frame, though each party tries to incorporate minor changes into the truce frame to get closer to their initial frame.

Triggers: The technology sensemaking process may be triggered by either situational or technological factors (Griffith 1999). The novelty of the technology or of any new feature may trigger the need for developing new related frames to understand and use the technology. Moreover, any discrepancy between observation and expectation leaves the individual unable to explain the situation and activates the sensemaking processes. Moreover, deliberative initiatives would require sensemaking activities; this could happen when the individual is asked to decide about or use the technology (Hsiao et al. 2008).

In addition, there are technology characteristics that may trigger sensemaking processes. The core features of the technology are more prone to sensemaking than the tangential ones. The core features are those that are critical for the overall identity of the technological system. Moreover, the concrete features of the technology are more likely to trigger sensemaking processes than the abstract ones. A technological feature is considered concrete when there are significant verifiable facts that can be attributed to the feature (Griffith 1999).

Social Context

Besides the cognitive processes that construct and maintain individual frames, there are some characteristics of the social context that influence how people make sense of the technology in organizations. While the cognitive aspect of technology sensemaking focuses on the cognitive structures and patterns on the basis of which people make and ascribe meaning to technology, the social aspect focuses on the social factors that facilitate technology sensemaking (Gephart 2004).

The structure of the social context affects how people make sense of the technology. For instance, sex segregation influences the cognitive frames that people adopt to understand technology in organizations. The workers in male- or female-dominated occupational positions are prone to develop quite different understandings about a robot deployed in a hospital (Siino and Hinds 2005).

The intensity of the social interactions between group members facilitates the congruence of the meaning they make about technology. For instance, technology frames of different user groups towards an electronic patient record (EPR) system were mostly similar because of the high interaction between groups (Karsten and Laine 2007).

The social and occupational roles that people play influences how they ascribe meaning to technological phenomena (Siino and Hinds 2005). For instance, various occupational groups in a hospital make sense of information system security in different ways and develop representations indicative of their work context (Vaast 2007).

Group belonging, social norms, power and influence are other social factors that affect technology sensemaking (Sneddon et al. 2009). People make sense of technology in such a way that their understanding does not conflict with the social norms and the meanings other members of the same group make. In addition, people intend to make the meanings that enhance their power position. Moreover, technology sensemaking of individuals is affected by the sensegiving activities of peers and powerful others. Such sensegiving activities are elaborated in the following section.

Sensegiving by Technology-use Mediators

After examining the cognitive and social aspects of sensemaking about technology, this section reviews the other side of sensemaking, sensegiving about technology. Sensegiving about technology is distinct from organizational sensegiving in that it focuses on concrete and objective technological features and functions that may further limit the sense being communicated by the sensegiver. Sensegiving activities are normally used by technology-use mediators to influence how others understand the technology in an organization. Technology-use mediators are individuals responsible for facilitating the adoption and adaptation of the new technology by users in the organization (Okamura et al. 1995). They use sensegiving to make sure the business value of IT is understood and realized by others in the organization (Gäre and Melin 2013).

Technology-use mediators employ various practices to influence user sensemaking. These practices are oriented towards changing either the users or the technology. While user-oriented practices focus on communicating the technological system and promoting use, the technology-oriented practices focus on adapting the system to fit the users and to easily communicate action possibilities to the users (Bansler and Havn 2006). User-oriented practices may include establishing use conventions, training users on how to use the system, and communicating the system functionality Technology-oriented practices may include inventing work-arounds and improving system usability that fits the technology usage to user needs and facilitates experimenting with the technology. Technology sensegiving is not only about communicating the appropriate meaning, but also about enacting the appropriate system that meets the needs of the users.

The frames that technology mediators develop and the practices they employ could be different during various phases of the technological change (McDaniel Albritton 2010). While the main concern of mediators, in the initial phases, is to install the system and get people to use it, later they are more focused on guiding people to make the best use of the system. In other words, the mediators' practices change from technology-oriented ones to user-oriented ones during the later phases.

DISCUSSION

Organization-technology sensemaking research has employed social and cognitive perspectives to examine the question of why and how people understand organizational phenomena, including technology. From a cognitive point of view, people start sensemaking when they face something new or ambiguous; then they extract the salient cues, draw on related mental models, categorize the cues, and label them with the appropriate meaning. The meanings are stored in the form of mental models that are continuously revisited to reflect people's new experiences. The social perspective examines how people's sensemaking is influenced by their social resources, including their schema and mental models, social interactions, culture, norms, and power relations. The notions of the collective mind, shared meaning, and consensus are central to the social aspect of the sensemaking processing.

In light of the current socio-cognitive understanding of the sensemaking phenomena, here we highlight three major shortcomings of the existing research. Next, we discuss the basics of an ecological approach that can potentially address these shortcomings. Finally, we discuss the research and practical implications of the ecological approach provided.

The Need for a Fresh Approach to Technology Sensemaking

Whereas past research has looked into cognitive and social aspects of the technology sensemaking phenomenon, it has paid less attention to other aspects. Here, we suggest three aspects that have been less attended to by the current approaches to technology sensemaking: lack of technology materiality; neglect of the discovery aspect of perception; and lack of action orientation across technology sensemaking research.

Lack of Technology Materiality

Latour (1992, 2005) noted that the artifact is absent in most sociological explanations of everyday life. Whiteman and Cooper (Whiteman and Cooper 2011, p. 892) affirmed that the organizational sensemaking research does not address the role of the "materiality of the natural world" in its explanations of the phenomenon. The same concern has been raised by many organization-technology scholars about the absence of the technology artifact in explanations of technological phenomena in organizations (Benbasat and Zmud 2003; Leonardi 2011; Orlikowski and Iacono 2001). This can be a valid concern as well for technology sensemaking

research, because there is barely any notion of technology materiality within the dominant socio-cognitive explanations of sensemaking processes.

Acknowledging this limitation, Griffith (1999) took the first steps to address the issue by examining how some characteristics of technology features would trigger the sensemaking processes. Her view recognizes the material artifact as a trigger of the sensemaking process; the more concrete and core the technological artifact is, the more probable it is to trigger sensemaking processes by the individual. However, she leaves unattended the role that the material artifact may play in shaping the meaning people attach to the technology.

Crystalizing the role of the material artifact in sensemaking processes will contribute to both research and practice in many ways. First, it extends the current understanding of the sensemaking process by going over the social and cognitive processes of sensemaking and highlighting how "the matter" about which people make sense can influence their understanding of new technology. Second, it brings traditionally socio-cognitive IS sensemaking research closer to the HCI and usability research so that these two disciplines can fruitfully exchange and contribute ideas. While usability research focuses on how design features are perceived and used, the sensemaking research can contribute to HCI research by explaining the role of the artifact in users' sensemaking of new technology. Third, it provides technology design teams with insights on how design features influence users' understanding and then adaptation to technology. It links the material artifact, its form and its features to how users make sense of the artifact.

Neglect of the Discovery Aspect of Perception

The current social psychological approach to technology sensemaking has dominantly assumed that meaning is fully made rather than discovered. In other words, the meanings that people ascribe to their environment are invented within the human mind using individual cognitive structures through their social interaction with others. However, Weick argued that "perception *creates* as well as reacts to an environment" (1969, p. 39) and clarified the fact that "sensemaking is about authoring as well as interpretation, creation as well as discovery" (1995, p. 8).

Despite Weick's acknowledgement, the discovery aspect of perception has been mostly neglected. While we know much about how perception creates meaning, we know very little

about how perception discovers the meaning already existing in the environment. This may be partly responsible for the lack of materiality in sensemaking inquiries that we mentioned in the previous point, because when the meaning is fully made within the individual's mind without anything out there to be discovered, there is no place for technology materiality to interfere with the process of meaning-making. For instance, the current perspective reveals that taxi drivers may perceive the GPS technology as either explorer or detector (Hou 2008; Hsiao et al. 2008). However, such a perspective neglects the fact that individual perception may refer to the specific material artifact discovered by an individual perceiver. The perception of the GPS system as explorer/detector may refer to the manual/automatic dispatching capabilities discovered by the taxi drivers.

Investigating the discovery aspect of user perception might have major implications for IS research and practice. First, it extends the dominant constructionist approach to user perception of technology to incorporate how some meaning is grasped as it already exists in the environment; it highlights the non-interpretive and more direct aspect of user perception. For instance, it highlights the fact that perceiving GPS technology as explorer of new customers partly reflects the capability of the manual dispatching feature to choose where to go and which customer to serve. This is part of the meaning already embedded in the GPS system and it takes the cab drivers some experimenting with the tool to discover such meaning. Second, investigating the discovery aspect of user perception facilitates the IS implementation processes by providing insights into which part of user perception could be constructed by technology mediators and which part is directly perceived from the technology itself. For the first part, mediators may focus on sensegiving and training activities, while for the second part they may focus on redesigning the technology features.

Lack of Action Orientation

Individuals' actions have a prominent position in Weick's account of the social psychology of organizing. To him, actions "provide the content for cognitions, and in the absence of action, cognitions are vacuous" (Weick 1969, p. 30). Action is the medium through which users grasp the discovery aspect of meaning, the meaning which is available in the environment. He believed that "too little attention has been paid to actions and too much to cognitions, plans, and beliefs" (Weick 1969, p. 30). Although he attested that action is an essential component of the

sensemaking process (Weick 2000), its prominent role has been only marginally appreciated across sensemaking studies, as well as in other areas like IS use research (Barki et al. 2007).

Actions are commonly examined in terms of activities and practices. Most technology sensemaking inquiries study how different understandings of technology enact specific practices (Hou 2008; Hsiao et al. 2008). Actions are seen as the product of sensemaking rather than as an antecedent. Although some sensegiving studies do study how the practices of a few sensegivers in an organization influence others' understanding of phenomena (Bansler and Havn 2006; McDaniel Albritton 2010), the question of how the actions of an individual or a group feed and influence the meaning they make has been mostly neglected.

Focusing on the role of users' actions in their sensemaking process will have various implications for IS research and practice. First, it extends the previous point regarding the focus on the discovery aspect of perception by explaining how the more direct part of meaning is actually discovered through user actions. Our understanding of the discovery aspect of user perception will never be complete unless we understand how it is discovered in action. Second, focusing on users' actions facilitates technology sensegiving practices of mediators by providing insights into what type of user actions should be encouraged to ease users' sensemaking of new technology. Moreover, it enlightens system design teams on what type of action should be supported by their design, so it facilitates users' sensemaking and meaning-discovery processes.

An Ecological Approach to Organization-Technology Sensemaking Research

To address the shortcomings of the current research, the ecological approach goes beyond the socio-cognitive understanding of sensemaking by linking the individual understanding of technology to the technological setting to which the individual adapts. It takes the meaning out of the black-box of the individual mind and links it to the unique relationship between the individual and the specific technological setting to which he or she adapts.

An Ecological Approach: What and Why?

Ecological psychology augments traditional cognitive psychology with an alternative explanation of human behaviour more consistent with Darwin's theory of evolution. The founders of the ecological school believed that the evolutionary theory provided a better understanding of how species adapt themselves to their environment and compete for survival.

This adaptive understanding of human behaviour required revision of dominant cognitive psychology, which seemed limited in its ability to explain the role that the environment plays in shaping human behaviour (Heft 1996).

Gibson (1986) re-examined human perception from an evolutionary theory perspective and came up with the ecological approach to perception that focuses on *interrelatedness* of natural entities as its defining idea. Consistent with evolutionary theory, this approach is mainly concerned with the *adaptive fit* between an individual and the environment. To be ecological, a theory should not only take *adaptation* as its central theme, but also keep its focus on the *environmental conditions* to which the species has adapted; such an environmental focus is both *relational* and *reciprocal* (Heft 1996). An individual's ecological niche comprises those features of the environment that bear a functional relationship to the individual. The ecological approach considers human behaviour as purposive goal-directed actions carried out in relation to an individual's niche. Individuals perceive their niche through detection of perceptual information that specifies the functional properties of the environmental features relative to the individual (Heft 1996).

From the ecological point of view, perception is always linked to action, and the intertwinement of the two facilitates the selection and adaptation processes of species in the environment. To explain this intertwinement and provide the link between perception and action, Gibson (1977) coined the notion of "affordance" to refer to the action-related perception of the environment and to establish the foundation for the theory of affordances. For Gibson (1986), an affordance is a possibility for action provided to the individual by its niche, and it is the building block of human perception. From this perspective, what people perceive when looking at their environment is not its substantive qualities and properties, but the action possibilities the environment provides in relation to the individual perceiver. For instance, when taxi drivers look at the extended screen of the GPS system, what they perceive is not the glassy window but the capability to provide the navigation information and obtain the touch input. However, such action possibilities are relational to individuals in the sense that the GPS screen may not mean the same thing to drivers and to passengers.

It is of immense importance to differentiate ecological direct perception from cognitive indirect perception. From the ecological point of view, affordances are not perceived indirectly through cognitive processes, but directly through the information that exists within the environment. In

other words, meaning is not invented in the individual's mind, but it is there within the environment and explored directly by the perceiver (Costall 1995; Gibson 1982; Greeno 1994; Heft 1996; Turvey 1992). Therefore, perception of affordances, in the ecological sense, is different from the cognitive perception that dominates the sensemaking research. However, highlighting the direct aspect of perception does not diminish the role that cognition plays in human perception; rather, it complements it. The direct and indirect ways are two aspects of perception, and cognition starts right after direct perception ends (Michaels et al. 2001). That is, people make inferences and build mental categories and models based on what they initially discover directly about the affordances of their niche. In this essay, to lay the ground for the ecological approach to sensemaking, we use the terms "perception", "exploration", "discovery", and "learning" of affordances interchangeably to refer to the direct perception of affordances. This is conceptually different from the normal, traditional use of the term "perception" in the cognitive sensemaking and IS literature.

From an ecological point of view, when individuals make sense about a new technology, they perceive the affordances provided to them by the technology artifact and its features. That is, they discover the action possibilities available to them rather than make new meaning cognitively to rationalize the new technology. Individuals' affordance perception is related to the technological niche to which they adapt. Technological niche is the specific combination of the technological resources to which the individuals adapt; it refers to the combination of technology features that the individuals use to accomplish their tasks. Individuals with the same technological niche form are considered to be members of the same user species. User species adapt to similar technological resources and perceive the technology affordances in similar ways. Moreover, over time, members of the same species develop some common characteristics and conventions that enable them to optimize their use of the resources available in their niche. These concepts of technological niche and user species are developed in further detail and illustrated empirically in a distinct but somewhat related study (see Essay 2).

For example, consider the ProjectWeb system used by Jean and Maria as described in the introduction. From an ecological perspective, Jean and Maria could be representatives of two user species that understand and adapt to ProjectWeb in different ways. Users of the species represented by Jean understand the system as a broadcast medium for one-way communication

of information. They probably adapt to those features of the system that allow them to post notes, announcements, and such. Moreover, they may develop and share the know-how for creating shortcuts to such features. In contrast, Maria would represent the user species whose members understand ProjectWeb as a groupware medium that lets them communicate and collaborate on various topics. Accordingly, they would adapt to certain features for two-way communication, file sharing, commenting, and such. In addition, they would develop and share the know-how for setting the notification capability so they would be notified when new messages come in or new files are shared with them; they may even develop higher teamwork skills compared to the other species represented by Jean. Such an ecological understanding of user adaptation to ProjectWeb links the user sensemaking of ProjectWeb (broadcast vs. groupware medium) to their adaptation to certain features of the technology and the characteristics they develop to optimize their use of certain features of the system.

We believe that an ecological approach to human perception has the potential to address the less developed aspects of technology sensemaking and further our understanding of the phenomenon in multiple ways. Firstly, the ecological view depicts an affordance-based relational human perception, rather than a frame-based cognitive one. Affordance-based human perception accounts for the materiality of technology, but not in terms of its absolute features. Materiality of technology is captured by the technological niche that provides relational affordances. The ecological approach explains various sensemakings and adaptations of the same technology not through cognitive models and different interpretations of technology, but through using multiple affordances provided by their niche (Mansour et al. 2013). In other words, people make different meanings about the same technology partly because they adapt to various niches that provide them with multiple and different affordances. This could offer one answer to the many calls for reviving the role of technology materiality in technology and sensemaking research (Leonardi et al. 2012; Orlikowski 2010; Robey et al. 2013).

Secondly, the central notion of direct perception appreciates the discovery aspect of perception. While the cognitive approach focuses on the meaning made in an individual mind through developing and maintaining mental models, the proposed ecological approach focuses on the less subjective aspect of the meaning discovered from the existing relationship between the

individual and their ecological niche. Such an approach highlights the less examined discovery aspect of sensemaking.

Lastly, the ecological approach provides an adaptive view of human behaviour in which perception and action are always tied to each other. Action and perception feed each other: people perceive while they are acting, and they act on the basis of what they perceive. Perception and action are intertwined in a way that one cannot be studied without considering the other (Michaels 2000). Conceptualizing human perception in terms of affordances, the ecological approach provides an action-oriented view of perception and facilitates examination of the link between action and perception.

Despite the prospects the ecological approach provides, its value has been marginally appreciated in technology research. IS design research is the main field that has thus far adopted an ecological view to technology and interface design; we briefly review this literature next.

Ecological IS Design

Rasmussen and Vicente (1989) provide the foundations for an ecological view on interface design by offering guidelines to ecologically design systems interfaces. They propose appropriate methods to implement those guidelines in interface design (Vicente and Rasmussen 1990, 1992). The means-end hierarchy can provide a framework for structuring the affordances of complex systems. This "abstraction hierarchy" identifies abstract goals on the top and relates them to the means of actualizing those goals in lower levels of hierarchy. It depicts not only the structure of the affordances, but also how they are related to each other.

The core to ecological IS design is the relationship between action and perception. There are methods and guidelines on how to facilitate this relationship through technology design. Rasmussen and Vicente (1989) summarized the ecological interface design in three guidelines: 1) merging the observation and action surfaces; 2) one-to-one mapping between the abstract properties of the internal process to be controlled and the cues provided by the manipulation/observation surface; and 3) displaying the process's relational structure to serve as an externalized mental model. They differentiate two streams of ecological psychology. Probabilistic functionalism recognizes both the direct and indirect modes of perception and is consistent with the cognitive explanations of human psychology. Direct perception is a

Gibsonian understanding of perception that denies cognition. Rasmussen and Vicente adopt the probabilistic functionalist approach and build a framework based on three levels of cognition within skill-based, rule-based, and knowledge-based human behaviour. Skill-based and rule-based behaviours need less inference and cognition, while knowledge-based behaviour uses representational inferences and is highly cognitive.

Relationality to the user is the other core component of ecological IS design. Hill (1999) provides an ecological understanding of information seeking in open-ended systems like the Web. She highlights the relational aspect of ecological design by examining how individual differences can result in varied information-seeking behaviours in open-ended systems. The level of user knowledge is shown to have implications for system use behaviour. These kinds of action orientation and relational nature need to be reflected in any ecological study of technology sensemaking. Next, we highlight the contribution of an ecological sensemaking to the larger body of IS research.

Shifting from Structuration to Critical Realism

To recognize the contribution of the ecological approach to sensemaking research, we consider its role within the larger body of IS research. Technology sensemaking research feeds the study of technology use and its consequences for organizations (Benbasat and Zmud 2003; Griffith 1999). While cognitive sensemaking contributes to structurational technology research, the ecological approach contributes to the growing body of critical realist research, particularly to the specific body of research that shifts from the structurational technology to the critical realist perspective.

The existing cognitive approach to sensemaking explains well how new technology brings consequences through structuration. It highlights the memory traces and technological practices that are stored and restored in the form of mental models and structures that not only construct future technology use and action, but also are constructed and reconstructed continuously throughout the sensemaking processes. However, the structurational approach is limited in explaining the role of the material artifact (Jones and Karsten 2008; Orlikowski 2005; Orlikowski and Iacono 2001; Rose et al. 2005). The Structurational Model of Technology (Orlikowski 1992) and Adaptive Structuration Theory (DeSanctis and Poole 1994) were among

the early efforts to adapt Giddens' Structuration Theory (Giddens 1984) to the study of technological phenomena. However, they both faced many criticisms for deviating from the essence of their origin because they assumed embedded structure into the technological artifact. From the structurational point of view, structures are emergent, and they are continuously reconstructed through individual practices; therefore, the user has the sole agency, and the practices they employ construct emergent structures. Then technology is nothing but the product of user practices. Such an approach makes it difficult to capture the role that the material artifact plays in shaping technological consequences.

Due to the insufficient treatment of the material artifact in explaining technological phenomena, there have been numerous calls for alternative approaches to IS research. There is a growing literature on the critical realist approach to studying technological phenomena (Collier 1994; Khoo and Robey 2007; Markus and Silver 2008; Mingers 2004; Mingers et al. 2013; Smith 2006). Critical realism can offer a shift from the Giddens' emergent structures to embrace the real structures that are consequential to organizations (Dobson 2001). Markus and Silver (2008) suggested that Adaptive Structuration Theory is more aligned with critical realist thinking than with Giddens' structuration: "the premise of [Adaptive Structuration Theory] that technology can be *a contributing* cause (though rarely, if ever, the sole cause) of patterns of IT use and consequences is much closer to the critical realist position than to those of positivism, interpretivism, or postmodern theories such as Giddens' theory of structuration" (p. 613). Critical realism takes the ontological position that admits the existence of realities independent of human knowledge. Such realities comprise mechanisms and structures with enduring properties (real) that have the potential to produce events (actual), some of which may be observed (empirical), thus providing a three-level ontological stratification of real-actual-empirical (Anderson 2011; Mingers 2004).

The ecological approach supports a critical realistic understanding of the technological phenomenon in various ways. First, the ecological approach is consistent with the three-level stratification of real-actual-empirical provided by critical realism (Volkoff and Strong 2013). The meanings that people explore, that is, the affordances provided to people, are real and exist independently of the individual's perception—this corresponds to the real level. However, the affordances may or may not come to individual attention and perception. People adapt to their

specific niche and actualize the related affordances. The individual goals, the range of availability and the amount of effort needed to actualize affordances could influence individual choices for actualizing affordances (Bernhard et al. 2013). The individual's niche is the domain of the actualities. This refers to what critical realism calls the actual level. The real affordances are potentials that may or may not come to the actual level. Moreover, even though many affordances may be unconsciously actualized, an individual may perhaps observe only a subset of the actualized affordances. The empirical level of critical realism refers to subset of actualized affordances that have been observed.

A second way that the ecological approach is consistent with critical realism is its support for the idea of generative mechanisms as the core structures that bring about technological consequences in organizations (Dobson et al. 2013). Generative mechanisms are the real "causal structures that generate observable events" (Henfridsson and Bygstad 2013, p. 911). While cognitively made meanings from cognitive sensemaking processes do not provide an adequate understanding of these causal structures that produce consequences, the ecological approach provides the affordances that could serve as the building blocks of the generative mechanisms (Volkoff and Strong 2013). Examining various adaptations, niches, species, and configurations of the affordances actualized by each species could reveal the mechanisms that bring about specific results for each species. Next, we follow this discussion with some of the implications of the ecological approach.

Implications of the Ecological Approach

The ecological approach provides fruitful insights about the non-cognitive aspect of the sensemaking processes that could feed critical realist inquiries of technological phenomena in organizations. It relates the various understandings of a technology to its technological setting and ecosystem, rather than to variations in interpretations; concepts like affordances, technological niches and user species facilitate this link between perception and the technological artifact. Exploring this relationship through an ecological lens has multiple implications for both research and practice, as is discussed in what follows.

Implications for Research

For research, the most prominent contribution of this study is to synthesize the current knowledge about how people come to varied understandings of organization-technology phenomena and to identify the shortcomings in our knowledge. In addition, this study takes the first steps towards providing an alternative approach to address some of those shortcomings. While the current approaches answer the question through the different mental models and knowledge structures that users have in mind about technology and the world (Davidson 2006; Orlikowski and Gash 1994; Vaast 2007; Weick 1990), the ecological approach presented here complements the traditional approaches by highlighting the point that the varied understandings of technology are supported by different aspects of a technology and of an individual. In other words, people come to different understandings through the different relationships they hold with various aspects of the technological artifact. The ecological approach brings the user's understanding of technology out of the black-box of the individual mind and relates it to the technological artifact and to the relationship between the artifact and the user. This is in line with many calls for reviving the role of the technology artifact in organization-technology research (Benbasat and Zmud 2003; Leonardi et al. 2012; Leonardi and Barley 2010; Orlikowski and Iacono 2001).

Action has always been closely related to individual perception (Weick et al. 2005). The dominant cognitive approach for the most part examines one side of this relationship, that is, how perceptions and beliefs influence intention and action, and how individual sensemaking affects user practices. The ecological approach highlights the role that individual action plays in shaping individual understanding of technology. In other words, while the dominant approach focuses on the effects of perception on action, the ecological approach focuses on the effects of action on the perception of new technology and how action facilitates sensemaking. It looks into the black-box of the "enactment" phase of sensemaking processes by examining the "exploratory behaviour" people employ to extract the meaning that is specifically appropriate to them. Since users act upon the technological artifact and the actions need to be supported by the artifact, any insights about the role of action in shaping perceptions could inform the role of the artifact in perception as well.

To theorize the role of the technology artifact and of action in shaping user understanding of new technology, the ecological approach draws on ecology and ecological psychology to depict the relationship between user, technology artifact, and action. The concepts and theories already developed in these fields enable organization-technology scholars to explore and explain the relationship between these three elements. The technological niche captures the artifact in relation to the user group that is adapted to it. User species identify users in relation to the artifacts they use. Affordance presents the unique capabilities provided to each niche-species group; it shifts the focus from either artifact or user to the relationship between the two. Such an approach could extend beyond the sensemaking research to explain how user species evolve and transform the technological niche to which they adapt, and provide the trends in adaptive behaviours over time.

Implications for Practice

The suggested ecological approach has important implications for managers and technology professionals. Identifying the various understandings of the technology and their relation to users and to the technology artifact could facilitate the process of technology implementation and mediation of technology use in organizations. For instance, consider the case of the GPS dispatch system introduced to taxi drivers (Hsiao et al. 2008) initially discussed in the introduction. As represented in Table 1-7, the ecological approach could identify the two user species who adapt to different technological niches as those who understand the GPS system as either “explorer” or “detector”. One differentiating aspect of their niche could be the manual/automatic modes of dispatching. While the explorers adapt to the manual mode, the detectors adapt to the automatic mode of dispatching. Moreover, the two species may be differentiated on some personal user characteristics. While explorers are risk-takers, the detectors are less prone to take risks. Furthermore, the members of each user species develop and share specific traits or conventions that could optimize the exploitation of their respective technological niches. In this case, the explorers develop the habit of identifying and sharing the hot-spots to be able to hunt for new customers using the manual mode. Moreover, the detectors could allocate and respect geographical territories for each driver to detect and serve the booked customers.

Table 1-7. The technology and individual aspects of drivers' understandings of GPS system

Understanding GPS as …	Technological aspect	Individual aspect	Practice conventions developed	Organizational consequence
Detector	Automatic dispatch mode	Risk-averse	Allocating and respecting territories	Retaining existing customers
Explorer	Manual dispatch mode	Risk-taker	Identifying and sharing hot-spots	Attracting new customers

Having such knowledge, taxi companies' managers would gain insight about different understandings that drivers have about GPS technology and how they are related to the technology and to individual aspects. This would inform their sensegiving efforts to promote specific understandings and demote others. If the company focuses on attracting new customers, then it prefers explorer drivers; thus it would promote the manual mode, employ risk-taking drivers and facilitate sharing the explorer conventions. If the company prefers to have a portfolio of both explorers and detectors, it would promote the manual mode of the GPS system to risk-takers and the automatic mode to conservative drivers. The technological niche to which either the explorers or the detectors adapt could include more than the single aspect of manual/automatic dispatch mode. The ecological approach provides rich insights on various aspects of the niche to which specific user species adapt and their relationship to individuals' understanding of technology.

For technology practitioners, the ecological approach could provide insights for improving the design of current technologies. Realizing which aspects of the technological artifact support the specific understandings of a technology would enable technology developers to design the technology in a coherent way that better supports those understandings. For instance, the technological niche to which the explorer drivers adapt may include various dimensions including the manual dispatching mode and customer profile browser. Having such knowledge, the designers may decide to incorporate the profile browser feature as highly visible and accessible in the manual mode, while it might be less visible and hence less distracting in the automatic mode. In addition, since explorers need multi-tasking abilities, designers could ease multi-tasking by enlarging the text and the map on the screen, or adding text-to-speech

capabilities or speech recognition to allow the drivers to talk with the GPS system. The availability of such capabilities would be more visible and accessible on the manual mode. Moreover, the designers could improve the GPS system by facilitating and supporting the conventions that the explorers have already developed; they could facilitate marking and sharing the hot-spots under the manual mode. These are examples of the kind of insights that the current cognitive approach to sensemaking has been ill-suited to provide.

Furthermore, the ecological approach reveals the activities that users employ to understand the technology. Redesigning technologies to support such actions could make technologies more understandable to users. For instance, Table 1-8 represents the hypothetical activities on which drivers could draw to understand the GPS technology. The table advises the GPS designers to support "practice" of the action possibilities. Such activities could be supported by making the users feel safe about the consequences of unfavourable outcomes. The undo, stop, resume, and reset capabilities would allow users to practise safely.

Table 1-8. Activity types that drivers employ to understand GPS system

Activity types	Description	Example for GPS system
Consider	Thoughtfully considering new concepts, symbols and information	• Looking all around the GPS system, its screen, buttons, etc.
Receive overview	Receive overview of the system through an interactive guide, map, presentation, or tour providing more information	• Taking the interactive tour when first activating the GPS system
Navigate	Navigating through the space provided	• Clicking through different tabs • Clicking in menu bar
Practice	Performing the action possibilities provided	• Clicking on options • Changing the settings • Finding a destination
Produce	Developing complete products and outcomes	• Finding the fastest path to the closest gas station
Apply	Applying the action possibilities provided to real world issues	• Using the system while driving
Evaluate	Testing the speculations and preferences, getting feedback, and observing and comparing the outcomes	• Checking if the system re-routes when a wrong turn is taken

		• Checking if the screen resolution could be changed
Create/innovate	Engaging in creative and imaginative applications of the possibilities provided	• Using the GPS system on a bicycle

As another example, Wikipedia provides a "sandbox" to each newcomer for practising the capabilities provided to them for editing articles. Since practising on real articles of Wikipedia may be damaging to the quality of articles, the sandbox lets people freely practise the possibilities provided. The sandbox is also useful for "producing" full articles and making sure every aspect of the wiki system is understood.

CONCLUSION

This essay reviews and synthesizes the current research on organization-technology sensemaking. It identifies three major shortcomings in the existing literature: lacking technology materiality, neglecting the discovery aspect of perception, and lacking action orientation. This essay lays the groundwork for an alternative approach based on ecological tenets consistent with a critical realist perspective.

The suggested ecological approach is aimed at reviving the role of the technological artifact in explaining how people understand technologies in organizations. I review the literature on technology-organization sensemaking and identify four major streams in organizational sensemaking research that treat sensemaking and sensegiving at the individual and collective levels. Figure 1-2 and Figure 1-3 represent the resources and practices on which individuals and collectives draw for sensemaking and sensegiving. Technology sensemaking research develops into two different streams. One examines sensemaking through technology and the design characteristics of the individual and collective sensemaking support systems (Table 1-5). The other investigates sensemaking about technology and the social and cognitive processes of understanding new technologies (Table 1-6). While the dominant approach to sensemaking research sheds light on many social and cognitive aspects of the sensemaking phenomenon, it rarely pays attention to the role that the material artifact may play in shaping various understandings of the technology-organization phenomenon.

To account for the missing role of the technological artifact in technology sensemaking research, the ecological approach we present here draws on concepts and theories from ecology and ecological psychology. Ecology examines how living organisms interact with and adapt to their environments. Ecological psychology investigates the role of ecology in human perception and behaviour. The theory of affordances and ecological niche theory provide insights and conceptual tools to examine how individual understanding of technology is related to individuals and to the technological artifact. According to the ecological approach, user understanding of technology is both functional and relational. It refers to action possibilities which are not necessarily equally provided to everyone; the availability of such action possibilities, called affordances, is dependent on certain characteristics of the individual. Moreover, these affordance understandings are explored through individual actions rather than made cognitively within the individual mind. It suggests that there are specific types of activities on which users draw to explore the affordances and understand the new technology. Furthermore, a user's understanding of a technology is related to the technological niche to which they adapt. The user species comprises the users who adapt to the same niche. The concepts of technological niche and user species lend themselves well to examining the relation between users and the technological artifact.

The present study has a few limitations. First, the ecological approach needs concrete conceptual and methodological tools before it can provide fruitful empirical insights. Further research is needed to elaborate and develop the ecological ideas to a full-featured theoretical framework with its related methodology. Second, no matter what the methodology is, any ecological inquiry would need diverse data that measure various aspects of users, technology and their interaction. So, the researchers would need to evaluate the feasibility of an ecological study before choosing to do one.

Consistent with the core tenets of critical realism, the ecological approach contributes to organization-technology research by shifting the focus from the memory traces of emergent technological structures to the existing mechanisms within the user-technology ecosystem. It supports critical realist technology research because it identifies the affordances (realities) providing the mechanisms that have the potential to trigger and conduct actions and events (actual) that may be observed (empirical). Finally, the ecological approach has important

implications for both research and practice that make it valuable for advancing current knowledge about technology sensemaking.

Transition to Essay 2

To address the role of the IT artifact in user sensemaking of and adaptation to technology, this thesis reviewed the current approaches to organization-technology sensemaking in the first essay. It synthesized the existing literature and highlighted the missing role of the IT artifact and how addressing the shortcomings of neglecting the IT artifact can contribute to research and practice.

The second essay goes on to propose an ecological approach that relates users' sensemaking of technology to users' adaptation to the material artifact. It theorizes the role of the IT artifact through the ecological concepts of technology affordance perceptions, technological niche, and user species. These ecological concepts provide the required conceptual tools to study users' sensemaking of technology in relation to their adaptation to its material artifact. In addition, the second essay proposes a unique combination of interviews, card-sorting, surveys and cluster analysis techniques to effectively adopt the suggested ecological approach in empirical inquiries of users' sensemaking of technology. Moreover, the second essay illustrates the proposed approach and the fruitful insights it suggests through an empirical analysis of users' sensemaking of and adaptation to a new system in a real-life scenario.

In all, the second essay follows and extends the first essay to propose and demonstrate an ecological approach that addresses the role of the IT artifact in user sensemaking of technology, which is the earlier phase of user-technology interaction.

Essay 2: Ecological Approach to Technology Sensemaking

ABSTRACT

Information Technology (IT) appears to have various intended and unintended consequences for organizations, and this is partly due to different understandings people have about the technology. Over two decades, sensemaking research has accumulated knowledge on how people understand organizational phenomena and attach meaning to them, mainly through varied social and cognitive processes. Despite some recent progress on materiality research, the role of the IT artifact in shaping the understandings and the consequences has been marginally addressed. This study proposes an ecological approach to technology sensemaking that focuses on the relation between users' perception of technology and the technological features to which they adapt. Moreover, it advances Information Systems (IS) research by providing new conceptual and analytical tools to examine the role of the IT artifact in IS research. To empirically illustrate the proposed approach and suggested methodology, we report the findings of an empirical study that applies and validates the framework.

Keywords: Technology sensemaking, IT artifact, ecology, affordance perception, user species, technoniche, Moodle

An earlier version of this essay was presented as: Mesgari, Mostafa and Chitu Okoli (2015). Ecological Approach to Technology Sensemaking. Proceedings of the International Conference on Information Systems. *Fort Worth, USA. December 13-16, 2015.*

INTRODUCTION

Information Technology (IT) has extensive consequences for organizations. There is ample evidence supporting the fact that users' understanding of technology significantly influences organizational consequences of information systems (IS). (In this study, we use the terms "technology" and "IT" interchangeably.) For instance, Savoli and Barki (2013) provided evidence that users who understand a healthcare system as facilitator, inhibitor, guardian angel or imposer assimilated the system at different levels and in various ways, then came up with very different results on how to successfully control their asthma. In another example, employees of two North American banks understood the new account management system as either controllable opportunity or uncontrollable threat for their jobs; whereas the former maximized their use and benefits of the system, the latter limited their use of the new system to decrease the disruption it caused them (Beaudry and Pinsonneault 2005).

In another example, cab drivers in Singapore understood and used GPS dispatching technology as either a "detector" of customers booked online or an "explorer" of new routes and hot-spots (Hsiao et al. 2008). While the first group could enhance the quality of service for the current customers, the second group could attract new customers; so they could help the company with either retaining or expanding its customer base.

Over two decades, sensemaking research has accumulated knowledge on how people understand technological phenomena and attach meaning to them, mainly through varied social and cognitive processes. Although the materiality stream of research addresses the role of the material artifact in bringing consequences to organizational structures and communications (Cecez-Kecmanovic et al. 2014; Orlikowski and Scott 2015), the role of the technology artifact is marginally addressed in shaping users' understanding of technology. The technological artifact is of key importance especially at the early stages of technology introduction and sensemaking, because it is almost the only thing on which new users can draw to make sense about the technology while the rules and conventions of use are not yet shaped (Hallerbach et al. 2013).

For instance, while the literature informs us on the "detector" and "explorer" understandings of the GPS technology by the cab drivers and their implications for their system use and work practices (Hsiao et al. 2008), it is mostly silent on how the two understandings refer to the GPS

features and design. Addressing this point would have important implications for managers and design practitioners. For one instance, managers of the cab companies can make informed decisions on promoting certain features of the GPS system to encourage the "explorer" understanding of the system if their strategy is to focus on expanding their customer base. For another, the system designers might highlight the related features to support either "explorer" or "detector" understandings of the GPS system. This study seeks to examine *the role of the technological artifact in shaping varied user understandings of new technology*. It addresses the many calls for reviving the role of the material artifact in explanations of technological phenomena in organizations (Benbasat and Zmud 2003; Leonardi 2011; Orlikowski and Iacono 2001).

This article presents *Ecological Technology Sensemaking* (ETS), which focuses on the relation between user perceptions of technology and their technological settings. ETS posits that what people understand about a new technology are *affordances* (Gibson 1977), that is, the functional relationships between the material artifact and the individual (Faraj and Azad 2012; Leonardi 2013a). As an example of this point of view, GPS technology affords drivers the ability to "detect" customers already booked online and to "explore" new routes and hot-spots. However, the technology does not provide affordances to everyone equally; rather, it depends on individual characteristics. The GPS technology may afford the drivers the ability to "explore" new routes and hot-spots if they are risk-takers.

Our ETS perspective adapts the concepts of ecological niche and species to the organization-technology research to extend the IS adaptation research (Barki et al. 2007; Ortiz de Guinea and Webster 2013; Sun 2012) and facilitate the examination of the relationship between the user and the material artifact. A *technological niche* (*technoniche*) is the part of the technological setting and resources to which the user adapts; it represents the way the user lives in the technological setting. A *user species* is a group of users who adapt to the same technoniche. The concepts of technoniche and user species permit the conceptualization of users and material environments in relation to each other. ETS suggests that the affordances people explore, or the meanings they make, are related to the technological niche to which they adapt. In other words, users who belong to the same species could explore similar meanings.

The contribution of this study is twofold. First, it complements the social and cognitive approaches to technology sensemaking by further theorizing the role of the technology artifact. Second, it extends materiality research by providing new conceptual and analytical tools to examine the role of the technology artifact in IS research. To empirically illustrate the proposed approach and suggested methodology, we report the findings of an empirical study on students using Moodle, a learning management system, in a North American business school. This dataset is particularly suitable for this study because 1) the student sample is not a proxy for any population but is the actual professional user group of the purposefully chosen system (Moodle) that we study; and 2) we do not intend to generalize the findings of the study beyond the student user group of this particular implementation of Moodle, although we use it as an illustration of the proposed ecological approach.

This article starts with a brief review of the technology sensemaking literature and highlights the missing role of the technology artifact in the extant research. Next, the Ecological Technology Sensemaking (ETS) framework is presented in terms of three propositions. Then the appropriate research methodology is laid out, and the empirical study and its findings are discussed, and then finally the paper is concluded.

TECHNOLOGY SENSEMAKING: REVIEW OF LITERATURE

Information systems and their entanglement with organizational features and practices are changing the way organizing unfolds by providing novel capabilities and affordances that support new forms of coordinating organizational work (Zammuto et al. 2007). Thus, technology is an essential part of every organizational phenomenon, and organizational scholars study technology sensemaking in order to understand how technology is enacted and woven into the organizational fabric. In this section, to clarify the nature of the contribution of ETS, we review some of the most relevant literature that has tried to understand how people make sense of technology in an organization.

Sensemaking is the process of attributing meaning to experiences (Louis 1980); or more precisely, it is the "ongoing retrospective development of plausible images that rationalize what people are doing" (Weick et al. 2005, p. 409). The fact that "sense makes organizing possible, and organizing makes sense possible" highlights the sensemaking processes as a crucial

component of doing and organizing because it is the process through which people understand their environment and attach meaning to it (Weick 2000, p. 95).

As a substantial organizational phenomenon, technology is always subject to sensemaking. It is recognized as being equivocal, admitting "several possible or plausible interpretations" (Weick 1990, p. 2). Technology is an equivocal reality understood in very different ways by various kinds of people in diverse contexts, and this makes it necessary for individuals and collectives to make sense of technology before acting on it. More than two decades of research on organization-technology sensemaking has provided us with valuable insights about the various aspects of the phenomenon. Here, we examine the three major streams of organization-technology sensemaking research: the cognitive, social, and materiality streams. While the three streams are not mutually exclusive, we highlight the core ideas of each.

Cognitive Stream

Technology is known as "*équivoque*" (Weick 1990, p. 2) as it lends itself to various simultaneous interpretations and understandings, which are processed and shaped through individual cognitive processes and mental models. There are many types of mental models that shape individual understandings of new technologies: 1) scripts include the sequence of actions for accomplishing a task (Weick 1990); 2) technological frames incorporate individual assumptions, beliefs and knowledge about the technology (Orlikowski and Gash 1994); and 3) social representations are collective mental models about how to behave in a social setting in general and may affect how one uses technology specifically (Vaast and Walsham 2005).

Whereas scripts are individual-level mental models (Weick 1990), the other two are collective-level models made and maintained within groups (Vaast and Walsham 2005). Among the three, technological frames are specific to the technology and its application in an organization (Orlikowski and Gash 1994), while the other two are more general, concerning how to behave in certain contexts which in turn may affect individual sensemaking and use of technology. These mental models guide individual sensemaking and behaviour in multiple ways. First, they not only affect individual behaviour but are also shaped and modified to reflect a person's new experiences (Orlikowski and Gash 1994). Second, the individual mental models are affected by the mental models of other socially and professionally relevant people in the organization, such

as their managers (Olesen 2014). Third, in the organizational context, while the congruence of the mental model would result in fruitful collaboration and technology use, incongruence most probably would lead to conflict and technology abandonment (Azad and Faraj 2008; Olesen 2014), unless it is treated wisely (Karsten and Laine 2007).

From a cognitive point of view, technological frames are made and maintained through processes at the individual and collective levels. At the individual level, sensemaking is triggered by some interruption, new features, or deliberate initiative of the IT department (Griffith 1999; Hsiao et al. 2008). Next, the frames are made and adopted, and then modified and used in the transitional phase; if they are consistent with individual experiences with the new technology, then they stabilize and automate user behaviour (Hsiao et al. 2008). In the individual-level processes, people tend to adopt and modify their frames to be consistent with their professional roles (Jensen and Kjærgaard 2010; Svejvig and Jensen 2013). At the group level, sensemaking is triggered by some disruption or conflict in the collaborative work. Next, people differentiate their frames from those of others with whom they interact personally and professionally, and then negotiate and modify their frames among themselves to increase the congruence of their frames. Finally, if the frames provide a working balance of multiple stakeholders' frames, they stabilize their negotiated frames and enable them to guide their behaviour (Azad and Faraj 2008). In group-level processes, people tend to adopt and negotiate their frames for congruity with powerful others.

In terms of their content, technological frames mostly unfold in one of several domain categories: technology features and attributes; potential organizational application of technology; incorporating technology into work routines and practices; the value of developing technologies in the organization (Davidson 2006); and the technology-specific frame contents (Hou 2008; Hsiao et al. 2008). In terms of their structure, frames may be pragmatic (focused on efficiency and usefulness of technology), romantic (focused on positive outcomes of technology), or pessimistic (focused on negative outcomes of technology) (Prasad 1993). In all, the cognitive approach to sensemaking explains various mental models and how they shape and modify meaning to guide individual behaviour towards technology.

Social Stream

Individual sensemaking of technology does not happen only cognitively and in isolation from others, but it also occurs in interaction with others in the social context. To complement the cognitive approach to technology sensemaking, the social stream of research focuses on the social and contextual factors that affect individual sensemaking of new technology. It examines a range of factors, including the social structure, occupational power, roles, norms, influence, interaction intensity and group belonging (Gephart 2004; Sneddon et al. 2009).

For instance, people tend to adopt different understandings towards a newly deployed robot in a hospital in a male-dominated social structure compared to a female-dominated one (Siino and Hinds 2005). In addition, people tend to make sense of technology in a way that is consistent with those of other socially and professionally powerful people, such as managers and organizational champions (Olesen 2014). They are also affected by the proactive sensegiving practices of others. Also, their sensemaking of technology would be more affected by people with whom they have more intense interactions. For example, groups with intense interactions developed similar understandings of an electronic medical record system in a hospital (Karsten and Laine 2007).

People tend to make sense of technology in a way that it is consistent with their occupational and social roles (Siino and Hinds 2005). For instance, in a hospital context, physicians and nurses make sense of technology related phenomena in different ways that are consistent with their occupational roles (Lapointe and Rivard 2005; Vaast 2007). In all, the social approach to technology sensemaking explains well how individual sensemaking is affected by various aspects of the individuals' significant social contexts.

Materiality Stream

There is a diverse stream of IS research that examines materiality, that is, the nonhuman aspect of technology sensemaking. Human-Computer Interaction (HCI) and User-Interface Design scientists are pioneers in studying the relation between design elements and user perception of the technologies (Norman 2004, 1988, 2002). Usability research is focused on how users understand the design of the material artifact. They draw on cognitive and social sciences and, more recently, on affordance theory to explain how affordances of the IT artifact could be

communicated to the user as the designer intends. To such researchers, good design communicates the affordances without any instructions. So they focus mostly on the "symbolic means" (Gaver 1991) and "conventions" (Norman 2004) that facilitate communication of the meaning that is designed in the technologies. Extending that path, Griffith (1999) argued that some characteristics of the material artifact trigger the sensemaking processes. All in all, their view is highly influenced by cognitive and social approaches to sensemaking because materiality is conveyed mostly through the "mental interpretation of things, based on our past knowledge and experience applied to our perception of the things about us" (Norman 2002, p. 219).

Recently, IS scholars have drawn on the materiality and sociomateriality approaches to account for the role of technology features in user adaptation to IS (Cecez-Kecmanovic et al. 2014; Leonardi 2013b). This stream examines the consequences of sociomaterial technologies and their related practices for the structures of work and the organization (Leonardi 2013a; Orlikowski and Scott 2015). It includes the role of the IT artifact on health practices of patients, nurses and physicians (Anderson 2011; Savoli 2014; Strong et al. 2014), that of design engineers (Leonardi 2011) and that of online community contributors (Hallerbach et al. 2013; Majchrzak et al. 2013). However, this stream of research marginally addresses the role that technology materiality plays in sensemaking and in shaping user understanding of technology. We intend to further extend this stream of research into technology sensemaking studies. Moreover, scholars of materiality research have highlighted the need for new conceptual and analytical tools to be able to account for the materiality of the artifact in explanations of technological phenomena (Orlikowski and Scott 2015). In the next section, we draw on ecology theory to answer this call.

In all, while the cognitive and social streams of sensemaking research are highly focused on the individual cognitive processes and the social processes and interactions that shape user sensemaking of new technology, they largely neglect the role of the IT artifact in shaping user sensemaking of technology. The more recent materiality stream of research examines the nonhuman aspects of technology adaptation, that is, how the IT artifact influences technology adaptation and work routines. We extend this body of research by proposing an ecological approach that examines how the IT artifact is related to users' sensemaking of new technology.

ECOLOGICAL APPROACH TO TECHNOLOGY SENSEMAKING

In light of the limitations of existing sensemaking research, this article presents a new ecological approach to technology sensemaking. Affordance theory originates from ecological psychology, which augments traditional cognitive psychology to explain human perception in a way consistent with Darwin's theory of evolution—perception is seen as a process of mutual adjustment with the environment. From the ecological point of view, perception is linked to action, and the intertwinement of the two facilitates the selection and adaptation processes of species in the environment. To explain this intertwinement and to link perception and action, Gibson (1977) coined the notion of an "affordance" to refer to the action-related perception of the environment as the foundation for the theory of affordances. People perceive the affordances of the niche to which they adapt and create species according to the similarity of their niches. We explain further the concepts of affordance perception, niche and species in the following. The general idea of the ecological approach to user sensemaking and the concepts of technological niche and user species are briefly presented in a distinct but somewhat related literature review (see Essay 1). This present study further develops the approach and the concepts in detail and illustrates them empirically.

Technology Affordance Perceptions

From an ecological psychology perspective, affordances are the building blocks of human perception. What people perceive when observing or interacting with the environment are the affordances provided to them. Affordances are the action possibilities "furnished" by the environment; they are real relationships that exist between the individual and the environment, rather than subjective meanings made cognitively in the mind (Gibson 1986). The information needed to perceive affordances may be acquired through vicarious learning or instructions, but direct exploratory activity is the primary means of actually learning and perceiving affordances.

The main premise of affordance theory is to highlight the non-cognitive aspects of human perception. People perceive affordances in the environment not though cognitive processes of categorization and labelling of the salient cues, but directly through sensing the unique specifying information and, more importantly, through action. Perception of affordances is as direct as perceiving that a specific colour is yellow (Gibson 1982). We perceive the colour even

before we learn that it is named and labelled yellow. The labelling and categorization of the colour yellow come after its perception to facilitate its communication to others.

Considerable evidence supports this basic premise, not least of which is research in developmental psychology that demonstrates that infants can understand many affordances of their environments early in life before they have developed any mental models (Adolph et al. 1993). Thus, perception of affordances in the ecological sense is different from cognitive perception that dominates the sensemaking research literature. However, highlighting the direct aspect of perception does not diminish the role that cognition plays in human perception; it rather complements it. The direct and indirect ways are two aspects of perception, and cognition starts right after direct perception ends (Michaels et al. 2001). That is, people make inferences and build mental categories and models based on what they initially discover directly about the affordances of their environment.

A technology affordance is defined as the "action possibilities and opportunities that emerge from actors engaging with a focal technology" (Faraj and Azad 2012, p. 238). It is the functional relationship an individual user has towards a technology artifact; thus, it cannot be defined or studied without considering both the technology artifact and the user (Leonardi 2013a; Markus and Silver 2008). From an ecological point of view, technology affordances are perceived directly without going through cognitive processes. However, technological frames and mental models may be created and revised on the basis of the technology affordance perceptions, which are the building blocks of user perception towards technology. That is, when people interact with new technology, the meaning they ascribe to the technology is the affordance they perceive.

Ecological technology sensemaking needs to study user perception of affordances in relation to their technological setting. To further conceptualize the relationship between technology affordance perceptions, the technology artifact and the user, we draw on niche theory to propose the concepts of technological niche and user species.

Technological Niche (Technoniche)

For about a century, niche theory has been evolving to explain how living organisms adapt to their environment. Early on, organisms were categorized and studied according to the geographic location in which they lived (e.g. Johnson 1910). The term "niche" was first used by Grinnell

(1917) and then developed by others to refer to the geographic and food habitat of organisms (Elton 1927; Gause 1934). Hutchinson (1973) took a large step forward by formalizing the niche concept as a multidimensional space of environmental resources in which an organism could survive. For instance, temperature and humidity are two critical resources for many living organisms. A given organism would be able to survive within a specific temperature range and a specific humidity range. The specific niche for that organism is the rectangular space identified by the temperature and humidity axes and within those specific temperature and humidity ranges. Other significant resources for the organism could be added to this space to make a more comprehensive multidimensional niche.

The ecological niche includes the part of the environment which is functionally meaningful and consequential to the organism (Heft 1996). It is the specific way in which the organism lives, the specific resources it employs to survive, and the part of environment to which it adapts (Hardesty 1975). The niche would be conceptualized in different ways depending on the level of analysis and the type of niche addressed. In terms of the level of analysis, the niche concept may be specified for an individual organism, species of similar organisms or population of varied organisms and species. In terms of the niche type, ecological niche may refer to fundamental, realized or partial niches (Hutchinson 1973; Vandermeer 1972). The fundamental niche includes the features and resources occupied under no competitive or population pressure. The realized niche is that which is occupied under specific conditions of the real world. The partial niche is the space occupied under a specific situation of competition with a particular organism or species. In most research inquiries, what is studied and represented as ecological niche refers to the realized niche rather than the fundamental one, because it is not easy to experimentally extract organisms from the real world pressures on their way of living.

To operationalize the multidimensional niche concept, ecologists can draw on two properties of the niche. First, the resources employed by the occupant organism represent the dimensions of the niche (for instance, humidity and temperature). Second, the degree to which the occupant organism is dependent on each resource to continue living is the relative importance of each dimension. For instance, one organism might be equally dependent on humidity and temperature, while another organism might be much more dependent on humidity than on temperature; the two organisms thus occupy different niches (Hardesty 1975). Since there are so many different

ecological resources, ecologists often have to limit the dimensions of the niche concept to the resources that are capable of differentiating the organisms (Levins 1968). When a specific resource is used homogenously by all organisms of a population, it would not be able to differentiate the varied lifestyles of species; thus it could be ignored as a dimension of the niche.

Organization research has drawn on ecology to define organizational niche as the specific way in which organizations operate and the combination of resources they employ to achieve their goals (Dobrev et al. 2002). For instance, Baum and Singh (1994) differentiated childcare centres based on the age ranges of the children they are allowed to admit, as this is the most essential resource they employ. In innovation studies, the technological niche would refer to the environment in which technological innovations are born and grown (Schot and Geels 2007); it may either be limited to the technical resources (Podolny and Stuart 1995) or extend to the economic, market, technical and cultural resources available for the innovation to grow (Bakker et al. 2012). For example, the number of startups that work in the same technological niche and the number of recent innovations within the niche seem to affect the growth and longevity of a new biotechnology startup (Ding 2011). Our present study is the first IS research study we are aware of that conceptualizes the technological niche at the user level rather than at the organizational level. Moreover, our conceptualization not only captures the various technological resources and features the users adopt, but also the level of their dependency on those resources.

To adapt the notion of ecological niche to technology research, we define the concept of technological niche, or "technoniche," as the distinct configuration of the technological resources to which the users adapt; it includes the technological features and resources the users employ to survive, or to do their tasks, as well as their dependency on each resource. It represents the users' distinctive way of technological life. It may comprise multiple dimensions that represent the level of dependency on different technological resources to which the users adapt. A technoniche, as we conceptualize it here, refers to the realized niche rather than the fundamental or partial niche because it is the niche that occurs under real-life conditions of technology use and reflects the current technology-in-use. The concept of technoniche may be useful in both IT and non-IT technological contexts; however, the exploration of specific implications of non-IT technologies is beyond the scope of this study.

The concept of technoniche enables realization of the ecological approach to technology sensemaking. It conceptualizes the technological artifact in relation to the user and permits examination of how the technological artifact is adapted by users with certain perceptions of the technology affordances. Capturing this relationship between the user and the artifact is key to the ecological approach to technology sensemaking.

We stress that we define technoniches at the species level rather than at the individual level; this involves groups of users who adapt to similar resources in a similar way. In the next section, we discuss such groups of users in detail.

User Species

The species is the unit of analysis for most ecological inquiries. It represents a class of individual organisms that are homogeneous within the class and heterogeneous in relation to other classes. Such homogeneity could be defined either reproductively (as in the biological species concept) or according to their relationship with their environment (as in the ecological species concept). Reproductively, species could be distinguished on the basis of their reproduction linkages that relate parents to children—this is the approach employed for the biological species concept. However, according to the ecological species concept, species are distinguished on the basis of the relationship they have with their environment (Valen 1976). In ecological studies, species have been defined for the most part ecologically rather than reproductively. Likewise, this study conceptualizes species in the ecological sense rather than in the biological sense; thus, there is no thought here of species in relation to reproductive behaviour.

Ecological criteria for defining species include the different resources that organisms consume, the spatial position of the resources and the temporal aspect of the resources (Hardesty 1975). For instance, species may be differentiated by uses of specific foods, the places they find foods, the seasons of the year when they can find their foods, and even the length of their life (Polis 1984). By classifying individual organisms into species, although some individual information may be lost in the more simplified picture presented by species, the general patterns of individual behaviour and resource consumption can be better revealed (Swaine and Whitmore 1988).

Species that occupy a similar niche develop functional traits exclusively adapted to their specific ecological niche (Pearman et al. 2008). A trait is a property or characteristic of an organism that

would affect its adaptation and survival. Species that live in a similar niche evolve traits that fit them to the selection pressures of their adapted niche. Developing such traits facilitates and strengthens certain adaptation patterns that may result in specific speciation (that is, formation into distinct species).

We note that in organizational studies, there is the concept of organizational ecology that likewise uses ecological theory to explain the birth, growth and decline of organizations with populations of organizations (often conceptualized as industries or sub-industries) (Betton and Dess 1985; Hannan and Freeman 1977; Pagano 1998). Although the ecological metaphors are apparently similar, ETS is fundamentally different, primarily in its unit of analysis. Whereas ETS takes human technology users as units and groups into user species, organizational ecology takes organizations as units and groups them into industries. Thus, there is little similarity between that body of literature and what we are describing here.

The concept of user species is also distinct from the somewhat similar concepts in the computer science literature: user profile and user persona. A user profile represents interests and preferences of users for recommendation and personalization systems (Godoy and Amandi 2009) and is created from either demographic data, descriptions of items the user has liked in the past or their previous ratings of items (Al-Shamri 2016). A user persona is a characterization of the target user of the system to give the system development team a better understanding of that user's needs and preferences (Cooper 1999). User personas can be created from user demographics, preferences and qualities (Pruitt and Grudin 2003). While user profiles and personas focus on the users themselves and on their interests and preferences, user species in ETS focus on users' resource consumption and interactions with the resources available. Therefore, a user species does not focus on the user's personal descriptive characteristics and preferences, but rather on how the users behave and interact with their environment. Such a fundamental difference makes user species conceptually distinct from user profiles and personas and renders user species a helpful alternative in HCI research because of its focus on user-technology interaction. The third essay of this thesis draws on the concept of affordances to provide an alternative approach for creating user personas.

Adapting the notion of ecological species to technology sensemaking research, this study defines a user species as a group of users who employ similar technological resources and occupy the

same technoniche. Users of the same species develop specific traits that enable them to adapt to the type of resources they use. Such traits may include behaviours, use conventions, procedures and tools that enable them to better exploit the resources they have. For instance, in the cab drivers example discussed in the introduction, the explorers would develop the habit of identifying and sharing the hot-spots so that they can locate more new customers. Similarly, the detectors could develop the convention of creating and respecting geographical territories for each driver as the primary service provider of that area for the detected customers.

The notion of user species could be quite valuable for technology sensemaking research in a couple of ways. Firstly, it provides a way for conceptualizing the user concept in relation to the environment. This departs from the dominant practice of conceptualizing and measuring users in terms of their individual characteristics or psychological status. Such an ecological understanding of technology users facilitates the examination of the relationship between users and their technological environment. Secondly, although the concept is defined at the group level and it may miss some of the user-related information at the individual level, it enables technology scholars and practitioners to understand the group-level patterns in user behaviour and the users' relationship to the technology.

Ecological Technology Sensemaking

To extend the materiality stream of sensemaking research and provide the new conceptual and analytical tools needed, we propose an ecological approach to technology sensemaking that focuses on the relationship between users' perceptions and the technological setting to which they adapt. This approach suggests that affordance perceptions arise from the specific relationship between the user and the technological artifact to which the user adapts. Figure 2-1 depicts the theoretical framework for an ecological approach to technology sensemaking. We note that the framework is a systems theory, not a variance theory (Burton-Jones et al. 2014; Nevo and Wade 2010). In systems theory, double-headed arrows are associations and interactions between subsystems (in our case, user species, user characteristics, and affordance perceptions), so the arrows are bidirectional relations representative of correlations rather than unidirectional causal influence.

Technoniche and user species are very close concepts that cannot meaningfully be defined independently of each other. Technoniche is defined at the species level of analysis, and any species is shaped by users adapting to the same technoniche. In other words, users belonging to the same species, by definition, are the ones adapting to the same technoniche. We cannot operationally identify user species unless we identify their technoniche at the same time, and vice versa. Having this point in mind, we provide three main propositions.

The affordances that users perceive are mutually related to the technoniches to which they adapt. In other words, users of the same species who thus adapt to the same technoniche develop similar affordance perceptions. The users who belong to a single species would explore similar affordances because they interact with similar resources and develop similar traits needed for the members of that species. This is consistent with the recent findings that the meaning people attach to a specific technology are affected not only by the affordances of the system, but also by the affordances provided by the larger technological niche to which the users adapt (Hallerbach et al. 2013).

Proposition 1. *The affordances users perceive are associated with the technological niche that they occupy and with the user species to which they belong.*

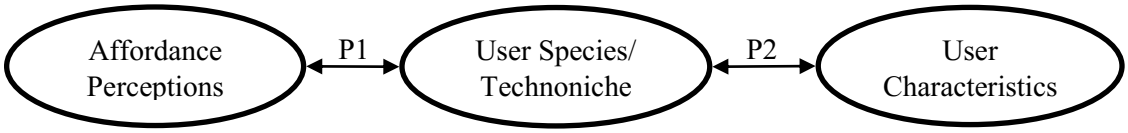

Figure 2-1. Ecological Technology Sensemaking

People live by adapting themselves to their ecosystem to make the best of the resources available. They not only choose the part of their ecosystem that best fits their characteristics, but also develop the functional traits and characteristics that fit the part of the ecosystem that they occupy (Pearman et al. 2008). ETS extends this premise to organization-technology research by suggesting that users of the same species hold or develop the specific characteristics that enable them to adapt to the type of resources they use. Such characteristics may include traits,

behaviours, use conventions, procedures or tools that enable them to better exploit the resources they possess.

Proposition 2. *The users of the same species that adapt to the same technoniche share some common user characteristics that facilitate their use of the technoniche resources.*

The proposed ecological approach addresses the limitations of the current socio-cognitive approaches to technology sensemaking, and explains the role played by the technological artifact. For instance, consider the example initially discussed in the introduction: cab drivers who understand the GPS dispatch technology as either "detector" or "explorer" of customers (Hsiao et al. 2008). From an ecological point of view, two user species could be identified with distinct technological niches: the "detectors" and the "explorers". While the explorers tend to adapt to the manual mode of the GPS dispatch system so they can ride around and locate new customers, the detectors would use the automatic mode of the system so that they are automatically assigned to the closest reserved customer. Moreover, the two species have some differentiating personal characteristics; whereas the explorers are prone to take risks, the detectors may be more risk-averse. In addition, the two species would develop and share certain traits and conventions to help them better adapt to and exploit their respective technological niches. For example, the explorers might consistently identify and share hot-spots so they could locate more customers in the manual dispatch mode. Such an ecological understanding of technology sensemaking explains how the cab drivers' sensemaking of the new technology (explorer vs. detector) is related to their technological niche (using manual vs. automatic mode) and certain personal characteristics (risk-taking vs. risk-aversion). It provides a more comprehensive picture of how users' sensemaking is related to their technological environments and personal preferences.

Adopting a species- and niche-based approach to technology sensemaking offers two advantages over the traditional purely cognitive approach. First, the concept of technoniche allows for analyzing how the technology artifact is related to the technology sensemaking of individuals. This is the missing relationship that has been challenging to capture and examine by current theoretical approaches in sensemaking research. Second, the concept of user species permits examination of the patterns in technology sensemaking and allows prediction of the sensemaking of users on the basis of the species to which they belong and the niche that they occupy. Such

analysis of patterns could be quite useful in redesigning and packaging technological products based on major user species and their related technoniches. Each concept is uniquely valuable because it conceptualizes technology artifacts and users not in absolute terms but in relation to each other. Such conceptualizations are quite powerful in examining the relationships between users and technology artifacts.

AN ILLUSTRATION OF ECOLOGICAL TECHNOLOGY SENSEMAKING

Any theoretical development is valuable inasmuch as it can fruitfully explain a focal phenomenon in the empirical world. For empirical application, theoretical models need appropriate methodological tools that enable scholars to capture and examine the concepts and relationships theorized. This section proposes a new sequence of existing research methods to measure users' affordance perceptions, technoniches, and personal characteristics and how they correspond to each other. To illustrate the fruitful insights that derive from adapting the ecological approach, we collected various data (interviews, computer usage log files, and survey responses) to explore and explain users' sensemaking of technology in relation to their technoniches and characteristics. It should be noted that the empirical study was conducted not for the purpose of supporting or rejecting any of the propositions in the sense of hypothesis-testing but to demonstrate the applicability of the ecological approach in an empirical inquiry and the meaningful insights it produces from a real-life scenario.

Proposed Research Methodology

We proposed a mixed-methods methodology drawing on qualitative and quantitative data and analysis to evaluate the insights provided by the proposed ecological approach, comprising the following steps:

1) *Interviews to extract technology affordances*: Conduct interviews and qualitatively extract the main perceived affordances of the focal technology. To extract the affordances of a new system, the interviewees should be users who are well experienced with the technological domain (Heft 2003). Because affordances are functional, the interviewees should have experience with the technical environment as well as the social context in which the use of a system takes place.

Qualitative analysis of rich interview data with experienced users is the main technique used to extract affordances of new technological settings (Mesgari and Faraj 2012; Strong et al. 2014).

2) *Survey to measure user perception of affordances and user characteristics*: Conduct a survey to measure the degree to which users perceive any of the technology affordances extracted from the interviews and also ascertain user characteristics. The survey items will be generated using the interview data, and then the survey can be validated using a card sorting exercise.

3) *Card sorting and cluster analysis to identify user species and technoniches*: Collect usage log data of the system and analyze it through clustering methods to identify the major user species that adapt to the same technoniches. We suggest using card sorting to identify the actions actualizing each affordance and then analyzing user actions at the level of the affordances that they actualize rather than at the levels of actions themselves; that is, aggregate user actions at the level of affordances before clustering them to identify species.

To aggregate user actions at the level of affordances, we suggest recruiting a few experienced users to identify which actions actualize which affordances through multiple rounds of a card sorting exercise (Moore and Benbasat 1991). These users should be given a list of actions (obtained from user logs) and a list of affordances (obtained from the in-depth interviews). Then they would be asked to imagine which affordance they are actualizing when they take any of the specific actions. Inter-rater reliability measures, such as Fleiss' kappa, would be used to demonstrate the degree of agreement among users about which actions actualize which affordances.

4) *Evaluate the species' sensemaking and characteristics*: Evaluate the difference in the average levels of affordance perceptions and of user characteristics across various user species. This step will identify how various species make sense differently about the focal technology and which user characteristics play a role in shaping the identified species.

It is important to note that the three concepts of species' technoniche, their sensemaking and their user characteristics are measured at the individual level and analyzed at the group level of species. Regarding the guidelines for multilevel theorization (Kozlowski and Klein 2000), we consider ETS to be a composition theory. This means that the three concepts at the species level of analysis emerge through convergence, rather than divergence, of their lower-level

counterparts. Consequently, averaging the individual level measurements is an appropriate measure of each concept at the species level of analysis. To empirically illustrate the ecological approach and the proposed methodology, we now report the implementation and findings of a study of a real-life scenario.

Description of Empirical Data: Students Using Moodle

Moodle is a free and open-source learning management system that is actively developed by Moodle HQ and a large community of volunteer contributors. As of May 2016, there were over 75,000 registered Moodle sites in over 225 countries, running over 9 million courses with over 85 million users.[1] Moodle is a particularly suitable technology context to test this theoretical framework for a number of reasons. First, it provides a wide variety of useful functionality to its users (students), yet the usage of many of these functionalities is not mandatory. Thus, users can self-select themselves into various species according to their own individual characteristics. This is a major advantage (for the purposes of this study) over many other organizational contexts with mandatory information systems. Second, all user actions on the system are logged. This permits us to examine actual system use in detail. Third, the users are readily available for interviews and surveys for some necessary aspects of the analysis. Fourth, we researchers are intimately familiar with the system, and so we understand various organizational and cultural issues that might affect the accurate interpretation of findings. Consistent with the guidelines suggested by Compeau et al. (2012), the use of students as subjects is perfectly suitable for this particular study for two reasons. First, the student sample is not a proxy for any population, but it is the actual professional user group of the purposefully chosen system (Moodle) that we are studying. Second, we do not intend to generalize the findings of the study beyond the student user group of this particular implementation of Moodle. Rather than generalizing, the study intends to use the empirical inquiry to illustrate the insights from an ecological approach to technology sensemaking.

Pilot Study

From February to April 2015, we conducted a pilot study to evaluate Moodle user species and their perceptions. We interviewed five users to identify the major affordances, and then designed

[1] https://moodle.net/stats/

and conducted the survey to evaluate users' sensemaking in regard to those affordances. Users' log data was collected and analyzed to identify the major user species and how they made sense differently about Moodle (Proposition 1 only). The pilot study is fully reported by Mesgari and Okoli (2015), and the methodological details are presented in Appendix 2-1 for further information.

The full study was conducted from July to December 2015. In addition to improving the methodological tools with insights from the pilot study's results, the full study evaluated Moodle user species in relation to both their perceptions and personal characteristics (that is, both propositions were illustrated). The steps for the full study are described below.

Step 1. Interviews to Extract Technology Affordances

The first step was to interview the users and identify the major affordances provided by Moodle. This step was conducted in common with a distinct but somewhat related study (see Essay 3), so it is described in more detail there; what follows is an abbreviated description of the procedure we followed and the results.

To recruit experienced users, we solicited about 400 undergraduate students of a North American university by email to apply for an interview session about their experiences with Moodle, with an offer of $15 compensation. 43 students applied, and we selected 12 well-experienced applicants for recorded interviews that took between 30 to 50 minutes each. The semi-structured interviews featured open questions about their experiences on Moodle. We added the five similar interviews we conducted during the pilot study to the pool of the qualitative data we collected, for a total of 17 interviews (see Appendix 3-2).

Using NVivo 10, the 17 interviews were transcribed and coded into every possible action, task and purpose the interviewees were describing. A second coder was trained and asked to use the coding schema to code a random sample of quotations that comprised 10% of the interview data. As a result, the original 33 codes were extended to 41, and over 100 quotations were recoded. The process brought about inter-coder reliability, kappa of 0.89. Next, the coded actions and behaviours were grouped into functional groups to facilitate meaningful affordance extraction (see Appendix 3-3 and 3-4). Five affordances were extracted:

- **Content Access:** Action possibilities enabling the students to access any course content that they need; these possibilities give the students read-only access to the course-related material.

- **Submission:** Action possibilities enabling the students to submit their work, answers, or ideas for part of their course grade, for which they might or might not receive subsequent feedback.

- **Communication:** Action possibilities enabling the students to communicate and share their ideas, opinion, and questions with the teacher, teaching assistants or fellow classmates; or to acquire awareness of what the teacher, teaching assistants or classmates communicated or shared; both parties have the chance to express themselves and engage in two-way interaction.

- **Practice:** Action possibilities enabling the students to practise what they have already learned about the course material.

- **Feedback:** Action possibilities enabling the students to get feedback on their learning, participation, submitted work or status or progress in the course.

Step 2. Survey to Measure User Perception of Affordances and User Characteristics

After identification of the major Moodle affordances, we turned to designing and conducting the survey to evaluate users' affordance perceptions and their relevant characteristics. While Moodle log data would be used to measure users' technoniches and their species, survey data would be used to evaluate users' sensemaking and their user characteristics. Preparation of the user perception and user characteristics parts of the survey and its administration are presented in the following.

User Perception of Affordances

We followed the instructions provided by Churchill (1979) and Moore and Benbasat (1991) to develop and evaluate the survey. First, we drew upon the interview data to generate items based on how students described their perceptions of the five affordances. Then we did a simple card sorting exercise and improved the items accordingly.

To pilot test this section of the survey, in March 2015, we invited 230 students to complete the survey and grant us permission to match their responses to their Moodle log data. 71 students participated. 8 surveys were not usable, so we analyzed the data for 63 participants for which we had both survey and Moodle log data. The Cronbach's alphas for the items measuring each affordance were above 0.7, which we judged acceptable. Confirmatory factor analysis was used to evaluate the discriminant validity of the concept measures (see Appendix 2-2). While most items loaded well on their respective constructs, some (mostly for Content Access and Feedback) did not load well. As a result, we revised the wording of 11 items, and completely replaced 3 other items. Among the five affordances, feedback was the only one measured by formative items—the other affordances used reflective items. While formative items measure multiple aspects of the focal concept and then add them together, reflective items measure a unitary aspect of the concept from multiple perspectives. So, while reflective items are expected to closely correlate with each other, it is not expected that formative items would converge and correlate (Cenfetelli and Bassellier 2009). Examining the formative items of the Feedback affordance perception, we can clearly identify multiple aspects of feedback being measured: the users could get feedback about their a) assignment submission, b) practice quiz or c) graded quizzes. So, we did not expect that users' perception of the Moodle Feedback affordance on three different aspects would load on a single factor. Therefore, we decided to keep Feedback as a formative construct to make sure it captures the full conceptual domain.

To double-check and make sure about the validity of the affordance perception items, we conducted a card sorting exercise using 10 doctoral candidates in business administration as judges. We sent them an Excel workbook with the definition of the affordances in one sheet and the list of survey items in another sheet; the survey items were randomized for each judge. We asked them to sort the survey items into the five affordance perceptions. In other words, they specified the affordance perception that they believed was being measured by each survey item. High agreement among the judges would demonstrate the validity of our measures. As a result, all items were consistently sorted into their related affordance concept with 80% and higher agreement among the judges, except for one item which was removed from the survey (see Appendix 2-3). That is, for each item but one, at least eight of the ten judges agreed on the affordance it measures. After removing the one disputed item, the overall inter-rater reliability, measured as a generalized kappa of 0.91, demonstrated high agreement among the judges and

thus high discriminant validity of the survey items. All affordances were measured with a kappa of higher than 0.83. As a result, the affordance perception survey included 29 items measuring Content Access, Submission, Communication, Practice, and Feedback affordance perceptions with six, four, ten, four, and five items, respectively. In addition, four reverse-coded items were included for the purpose of response quality verification; these were not included in the data analysis.

User Characteristics: Students' Learning Style

To explain user adaptation to and sensemaking of Moodle from an ecological point of view, we needed to identify the users' characteristics and preferences that affected their adaptation and speciation. To find user characteristics that affected Moodle use, we examined previous research in the areas of IS usage as well as usage of knowledge management systems, learning management systems and, more specifically, Moodle.

Learning or cognitive style appears to be one of the major characteristics affecting IS use in general (Jasperson et al. 2005) and, more specifically, the use of learning technologies (Allinson and Hayes 1996; Chung and Ackerman 2015; Núñez et al. 2011). Learning style is defined as "consistent individual differences in preferred ways of organizing and processing information and experience" (Messick and others 1976, p. 5). Individuals with various learning styles are expected to use and benefit from learning technologies in different ways (Vigentini 2009), so we expected it to affect the way students choose to adapt to and use Moodle. In addition, age, gender and experience with the focal technology are the other user characteristics widely found to influence user adaptation to technology (Chung and Ackerman 2015; Jasperson et al. 2005; Venkatesh et al. 2003). These three, plus the learning style, are the user characteristics that we investigated for possible influence on users' speciation in the Moodle setting.

It is important to note that our study of these four characteristics is of a more exploratory nature than a confirmatory one, as is our empirical study. In other words, we do not claim or expect that all or any of the user characteristics necessarily play a role in differentiating the user species; rather we explore and identify if any of them affect Moodle user speciation. Similarly, we do not claim that we have captured all user characteristics relevant to the use of Moodle. However, the more comprehensive researchers can be in their identification of relevant user characteristics at

this phase, the more chance they would have of explaining user speciation and adaptation in a specific technological context.

To measure users' learning style, we used the Index of Learning Style (ILS) questionnaire because it comprehensively evaluates four dimensions of individual learning style as per the following (Felder and Spurlin 2005, p. 103):

- "*sensing* (concrete, practical, oriented toward facts and procedures) or *intuitive* (conceptual, innovative, oriented toward theories and underlying meanings);
- *visual* (prefer visual representations of presented material, such as pictures, diagrams, and flow charts) or *verbal* (prefer written and spoken explanations);
- *active* (learn by trying things out, enjoy working in groups) or *reflective* (learn by thinking things through, prefer working alone or with one or two familiar partners);
- *sequential* (linear thinking process, learn in incremental steps) or *global* (holistic thinking process, learn in large leaps)."

The full ILS questionnaire includes 44 items, 11 items per dimension. For each item, the respondent has to choose one of the two available options, "a" or "b", each related to either side of the dimension (e.g. sensing vs. intuitive) (see Appendix 2-4 for specific examples). The respondent's score for each learning style is computed by deducting the number of "a" responses from the number of "b" responses for the 11 items related to that style, as explained in Felder and Spurlin (2005).

Since the final survey would be too long if we combined the full ILS questionnaire with the 33 affordance perception items, we followed the guidelines provided by Stanton et al. (2002) to reduce the length of the scale while maintaining the content validity of the full questionnaire. We ran the full ILS scale on Amazon Mechanical Turk (MTurk), a crowd sourcing labour website. Following many studies supporting external validity of the data collected using MTurk (Buhrmester et al. 2011; Casler et al. 2013; Huff and Tingley 2015), we were able to reproduce a representative sample of a student community for testing and reducing the ILS instrument. We designed the full instrument on Qualtrics and put its link on MTurk for students aged from 18 to 22 to participate for $1.50 compensation for about 10 minutes of their time. We screened students from non-students by using a brief demographic test that respondents had to complete

before being permitted to do the main survey. We did not tell the respondents which demographic profile we were looking for. During the two days the survey was available on MTurk, it was accessed more than 2,200 times, and 104 respondents (less than 5%) passed the eligibility screen as students 18 to 22 years old. Among these, 25 responses were removed because of either low quality responses or because they appeared to be fake students, indicated when the same IP address accessed the survey multiple times around the same time (indicating that they probably repeated the pre-screen test until they qualified). We analyzed the data for the remaining 79 respondents.

Since the ILS is composed of formative items, we used EFA to explore the dimensionality in each of the four aspects of learning style. Then we chose five of eleven items for each aspect in the way they represent major dimensions identified by EFA; this ensured that the reduced instrument captures most of the concept domain and provides the highest content validity. Table 2-1 gives Levene's test and the dependent sample t-test that examine if the learning style score for the full and the reduced instruments are equal in variance or mean, respectively. The hypothesis of equality of the mean of the learning style scores is not rejected for any four of the learning style dimensions. Moreover, the Levene's test for homogeneity of variance for the full and reduced instruments is supported for two of the learning styles (visual and sequential) at the 5% level, and it is marginally supported for another style (active) at the 10% level. Thus, we used the reduced instrument of 20 instead of 44 items to measure Moodle users' learning style in our study (see Appendix 2-4). The learning score for each dimension was the number of "a" choices minus the number of "b" choices among the five items for each dimension. Therefore, the learning style score was a number between 5 to -5 for each dimension.

Table 2-1. Levene's test for equality of variance, and dependent sample t-test for equality of mean

Learning style dimension	Levene's test (F value)	Levene's test (P-value)	Mean for full instrument (44 items)	Mean for reduced instrument (20 items)	Mean of differences	P-value
Active	2.72	0.10	-0.72	-0.65	-0.07	0.591
Sensing	1.56	0.21	-0.11	-0.11	0.00	0.977
Visual	5.12	0.02	1.61	1.41	0.20	0.223
Sequential	22.51	0.00	0.50	0.59	-0.09	0.655

User Survey Administration

The survey, including affordance perception items and items about user characteristics (including the learning style items), was designed in online and print versions (see Appendix 2-5 for the print version). We invited students in three courses at a North American Business School to participate in our study. We chose our particular sample for the following reasons. First, the three courses use Moodle in a very extensive and generally similar manner: they provide course material, quizzes, grade notifications, forums and assignment submissions on Moodle. Second, the three courses were divided into multiple sections of over a hundred students each, for a total of 15 sections; this gave us a large sample of users within a homogenous context. The three courses were coordinated, so all sections of the same course had common course outlines and modules, and all used a shared Moodle template.

We conducted the survey in late November 2015 by which time the students had been using Moodle for at least 10 weeks of a 13-week semester. The participating instructors agreed for their students to participate either online only or in-class with an online option. In 6 sections out of 15, we had the opportunity to attend the last 15 minutes of the class, explain the study and ask students to voluntarily participate in our study by completing the printed survey. Afterwards, the students in these classes were sent an email with a link to the online survey so that absent students could also participate. For the other 9 sections, we visited their classes and briefly explained the study and invited them to participate in our study by completing the online survey; afterwards, they were sent an invitation email by their professor and were provided with the full instructions and the link to the online survey. All respondents were informed that their participation authorized us to access their Moodle usage logs (not including their actual grades or scores) and link their Moodle usage to their survey responses. All respondents of either version of the survey were offered $5 compensation, which they received during office hours scheduled later.

From about 1500 students invited to take part, a total of 372 students participated. We could not identify 4 of them by name, and so we could not match their Moodle log data. 37 other responses were removed because of low quality of data by using some check questions. For instance, we

inserted a Likert scale question that read "If you read this question, choose the option number four." Some respondents who did not read the questions carefully were identified by their wrong answer to this question. 331 survey responses were valid.

Table 2-2 summarizes the demographics of the survey respondents and their learning styles. The ILS scale has only values of -5, -3, -1, 1, 3 and 5. Consistent with Felder and Spurlin's (2005) recommendation, learning style scores of 1 and -1 are considered balanced on the two sides of the scale, scores of 3 and 5 are considered a solid preference for one side of the scale (e.g. Active style), and scores of -3 and -5 are considered a solid preference for the other side of the scale (e.g. Reflective style). In the next phase of the study, we measured the users' technoniches and identified their species.

Table 2-2. Demographics of the survey respondents

Demographics	Value	Minimal Users (S1)	Moderate Users (S2)	Maximal Users (S3)	Non-clustered	Total Frequency
Age	20 & under	44	51	13	6	114 (34%)
	21 to 25	99	57	14	12	182 (55%)
	26 & above	12	17	3	3	35 (11%)
Gender	Male	81	52	13	10	156 (47%)
	Female	74	71	17	11	173 (52%)
Major	Accountancy	37	32	4	5	78 (24%)
	General Business Administration	9	7	2	0	18 (5%)
	Business Technology Management	5	9	2	0	16 (5%)
	Marketing	13	12	2	0	27 (8%)
	Economics	12	11	1	2	26 (8%)
	Finance	30	16	8	7	61 (18%)
	Management	9	6	0	2	17 (5%)
	Human Resource Management	6	11	1	1	19 (6%)
	International Business	20	14	7	4	45 (14%)
	Supply Chain Operations Management	7	5	3	0	15 (5%)
Number of Moodle courses enrolled (including present course)	1 to 2	11	4	1	3	19 (5%)
	3 to 5	67	73	16	9	165 (50%)
	6 & more	77	48	13	9	147 (44%)

Active/ Reflective	Active	33	29	5	2	69 (21%)
	Balanced	85	73	17	16	191 (58%)
	Reflective	37	23	8	3	71 (21%)
Sensing/ Intuitive	Sensing	86	73	22	15	196 (59%)
	Balanced	57	42	7	5	111 (34%)
	Intuitive	12	10	1	0	23 (7%)
Visual/ Verbal	Visual	102	65	15	10	192 (58%)
	Balanced	42	40	11	10	103 (31%)
	Verbal	11	20	4	1	36 (11%)
Sequential/ Global	Sequential	55	48	10	10	123 (37%)
	Balanced	82	63	18	8	171 (52%)
	Global	18	14	2	3	37 (11%)

Step 3. Card Sorting and Cluster Analysis to Identify User Species and Technoniches

After measuring users' affordance perceptions and their relevant characteristics, we turned to measuring the users' technoniches and identifying their species. To do so, we took the following two steps and analyzed users' log data at the level of the affordances they actualized.

Card Sorting: Identifying Actions That Actualize Each Affordance

For this step, a card sorting exercise was employed to understand how user actions on Moodle actualized the five major affordances identified from the interviews. Like the previous card sorting exercise mentioned in Step 1 above, this exercise was used in common with the same distinct but related study (see Essay 3), so it is further described in detail there; what follows is an abbreviated description of the procedure we followed and the results. A list of 53 different actions was extracted from the student log data (see Appendix 2-6). For instance, starting to do a practice quiz (quiz_attempt), submitting an assignment (assign_submit), and posting a new discussion to a forum (forum_add discussion) are among the actions available to the users. We conducted two rounds of card sorting in which we asked 15 experienced student users (5 for the first and 10 for the second round) to sort each of the 53 identified user actions into one of the five identified affordance categories. The first round resulted in a satisfactory inter-rater reliability, Fleiss's kappa of 0.78; a kappa higher than 0.65 can be considered acceptable (Moore and Benbasat 1991). The first round of card sorting resulted in some changes to the action definitions. We conducted the second round of card sorting with 10 student experts. Six of the actions got an agreement of less than 80% in their sorting in both rounds, so we removed them

from the list of actions. After removing these problematic items, the overall kappa was 0.90, with no individual affordance having an agreement lower than 0.83, which demonstrated substantial agreement among the ten students. Thus, no further rounds of card sorting were needed. Table 2-3 displays the final list of which actions corresponded to each affordance. Appendix 2-6 lists all the actions with their full definitions as they were used in the card sorting exercise.

Table 2-3. Card sorting exercise results: actions that support each affordance

Affordances	Moodle Actions that Actualize the Affordances
Content Access	assign_view (before submission); assign_view all; book_view; book_view all; book_view chapter; course_view; data_view; folder_view; folder_view all; imscp_view all; label_view all; lti_launch; lti_view all; page_view; page_view all; quiz_view (for graded quizzes); resource_view; resource_view all; url_view; url_view all
Submission	assign_submission statement accepted; assign_submit; assign_view submit assignment form; data_add; data_update; quiz_attempt (for graded quizzes); quiz_close attempt (for graded quizzes); quiz_continue attempt (for graded quizzes)
Communication	discussion_mark read; forum_add discussion; forum_add post; forum_delete discussion; forum_delete post; forum_subscribe; forum_unsubscribe; forum_update post; forum_view discussion; forum_view forum
Practice	quiz_attempt (for practice quizzes); quiz_close attempt (for practice quizzes); quiz_continue attempt (for practice quizzes)
Feedback	assign_view (after submission); quiz_review (for practice quizzes); quiz_review (for graded quizzes); quiz_view all; quiz_view summary (for practice quizzes); quiz_view summary (for graded quizzes)

Cluster Analysis: Identifying Species with the Same Technoniches

In the second step of identifying user species, we employed log data on students' Moodle usage during the Fall 2015 semester; the students responded for 15 different sections of three different courses. Since the three courses were coordinated courses, all sections of each course used the same Moodle template created by the course coordinator. Our dataset compiled 259,351 actions conducted by 331 students from whom we received valid survey responses.

R version 3.2.0 was used, including its base package (R. Core Team 2015), the cluster package (Maechler et al. 2015), and the ggplot2 package (Wickham and Chang 2015) to conduct hierarchical clustering. Some of the tables and analyses in the appendices were created using SPSS 20. We had to pre-process the log data before we could analyze it. For instance, we had to distinguish practice quizzes from graded quizzes so that we could properly analyze their related actions. The two types of quizzes were named differently, which made it easy to differentiate them. Moreover, unlike the practice quizzes, the graded quizzes had to be submitted within a 24-hour period by all students, so the variance of the submission dates was a clear criterion to differentiate the two types of quizzes.

The agglomerative hierarchical clustering procedure used in this study starts with one cluster for each data point and then computes the closest clusters and merges them into one cluster. This process of agglomeration continues until the algorithm gets to one general cluster including all data points. We employed a clustering method based on between-group linkages in which the average distance between each two members of every two clusters are computed and the two groups with the smallest average distance are merged. Furthermore, we chose the Euclidean distance measure because our goal was to identify species whose use of technology corresponded to their perceptions. Thus, we expected that the level of affordance actualization would correspond to the level of affordance perception.

At first, we used all the five affordance actualizations to cluster the users and identify the species. Appendix 2-7 presents the dendrogram for the hierarchical cluster analysis. We came up with three different species. While four of the affordances could significantly differentiate some of the three species, the Communication affordance was not able to differentiate any pair of the three species (see Appendix 2-7 for ANOVA results). Therefore, we removed it from our cluster analysis. Moreover, since the Submission affordance was always actualized by the users to fulfill a mandatory feature of their course (that is, they were required to submit assignments on Moodle to receive a grade), we did not expect it to be related to the users' perception and sensemaking of the new technology. This is consistent with extant IS use literature, which attests to a reduced relationship between user perception and intention to use a system in mandatory use settings (Venkatesh et al. 2003; Wu and Lederer 2009). Thus, we repeated the cluster analysis with only

the three voluntary affordance actualizations that properly differentiated the species (Content Access, Practice, and Feedback). Figure 2-2 is the resulting dendrogram.

We chose to cut the dendrogram tree at the height of 330, which means the resulting clusters are more than 330 actions different from each other in terms of the average Euclidean distance between their members. The reason for our choice is that it gives us three significantly large clusters with somewhat good distance from each other. We removed the five singleton clusters as outliers. Moreover, we did not consider the three cliques with two to five members as major species.

So, three clusters identified on the dendrogram represent three species of students who adapt differently to Moodle. They respectively include 155 (47%), 125 (38%) and 30 (9%) members of the sample user population, representing 310 (94%) of the 331 users sampled. Figure 2-3 and Figure 2-4 depict respectively the technoniches of the three species based on the actual and standardized number of actions. While Figure 2-3 keeps the original scale to highlight the differences in the frequency of actualizations between the three affordances, Figure 2-4 standardizes the scale to focus on the differences between the three species for each affordance. Species 3 (S3) depends on the Practice, Content Access, and Feedback affordances at the highest levels compared to the other species; we call it the "Maximal" user species. Species 1 (S1) is the least dependent on the Practice, Content Access, and Feedback affordances compared to other species, so we call it the "Minimal" user species. Species 2 (S2) is moderately dependent on the Practice and Feedback affordances while actualizing the Content Access at a level comparable to that of the Maximal species, so we call it the "Moderate" user species. Although the names "Minimal", "Moderate" and "Maximal" might suggest simply users who are more or less active in using Moodle, the insights and implications that we discuss in the Discussion and Conclusion sections below show that our ecological analysis unveils far more nuanced portraits of these user species than stereotypes might suggest.

To examine if the resulting species are affected by our aggregation of data from various sections taught by various instructors, we compiled the contingency tables for the members of the three species across either sections or instructors (see Appendices 2-8 and 2-9). The standard residual for all cells was less than 1.96 (which represents the 0.05 confidence level), so there is no reason to believe that any differences between sections or instructors affected the species we identified.

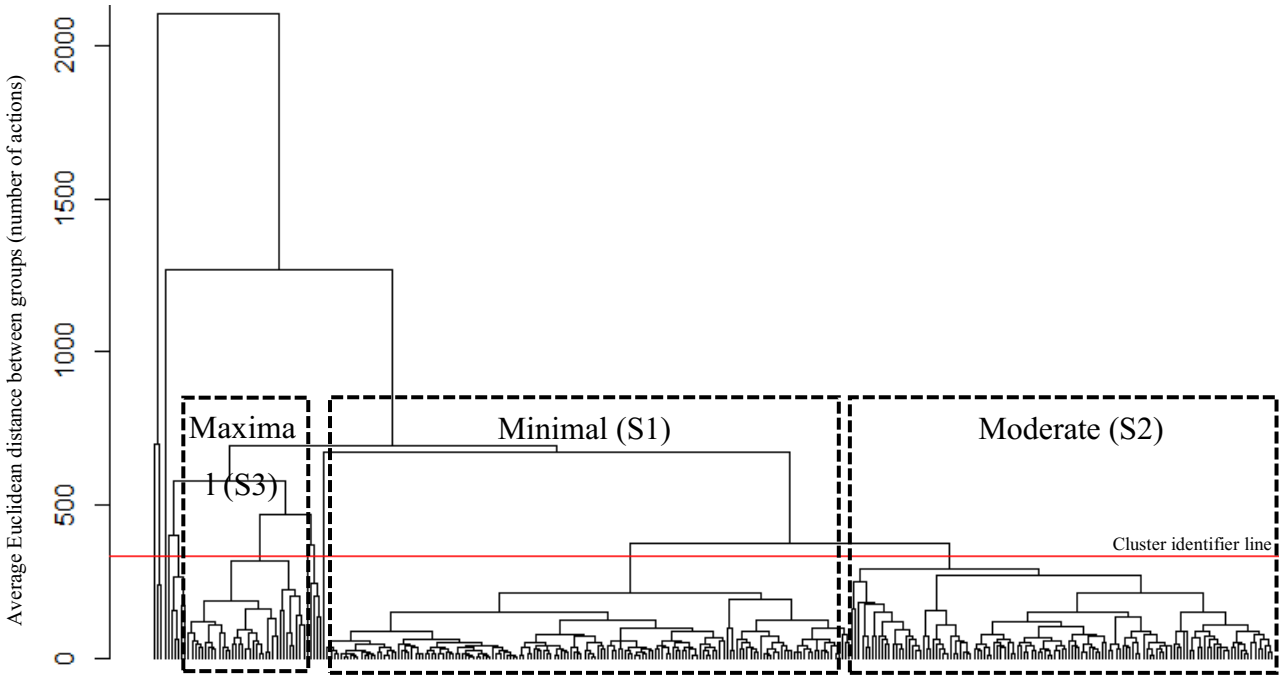

Figure 2-2. Dendrogram from Hierarchical Cluster Analysis

We used ANOVA to test if the identified clusters (user species) actualized affordances differently from each other. Specifically, for each affordance actualized, we tested if the average number of actions of the three identified clusters were equal. This hypothesis was rejected for all three of the affordance actualizations (see Table 2-4), meaning that for each of Content Access, Practice and Feedback affordance actualizations, at least two of the three clusters were quite different. Two-by-two comparisons using Tukey HSD tests showed that most of the comparisons for all affordances were significant (see Table 2-5). All in all, the three clusters are representative of three distinct species having significantly different adaptation to Moodle. In the next phase, we evaluated the relation between the species' technoniches and their sensemaking and characteristics.

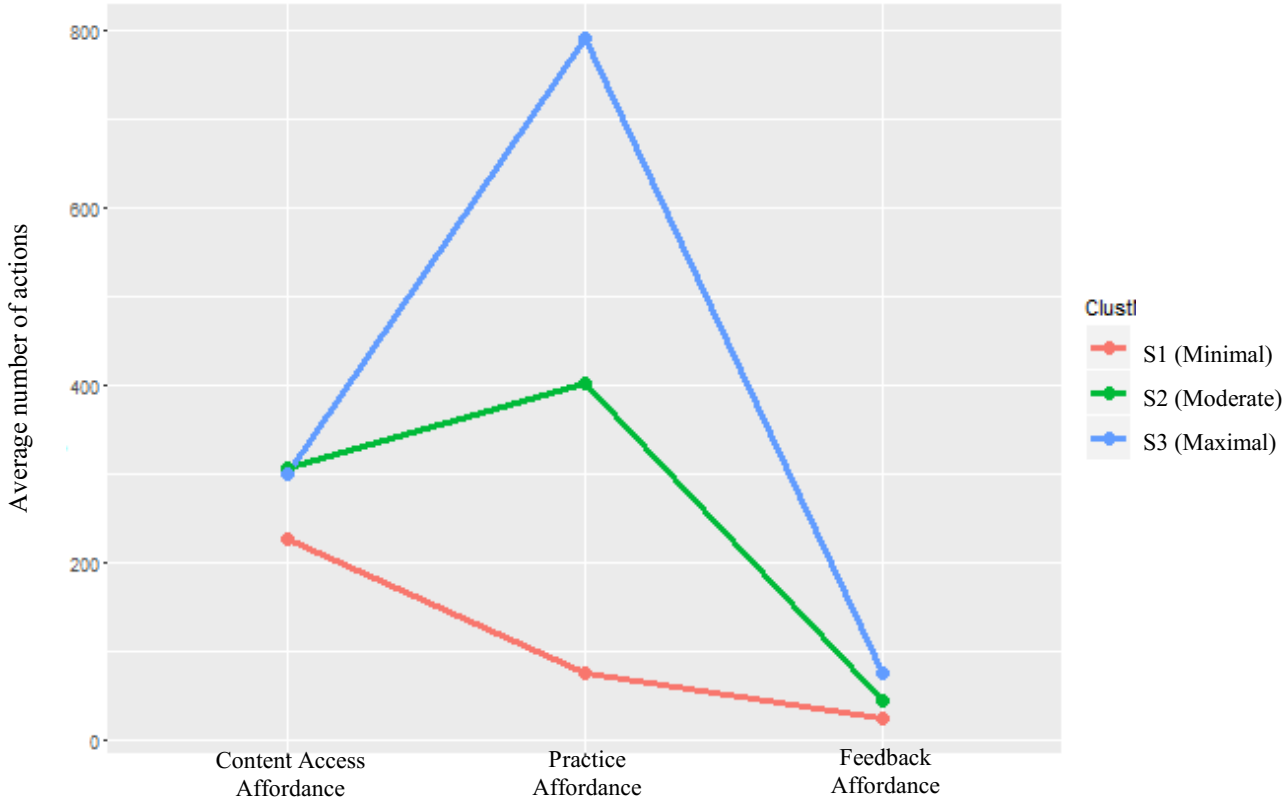

Figure 2-3. Average number of affordance actualizations (log data)

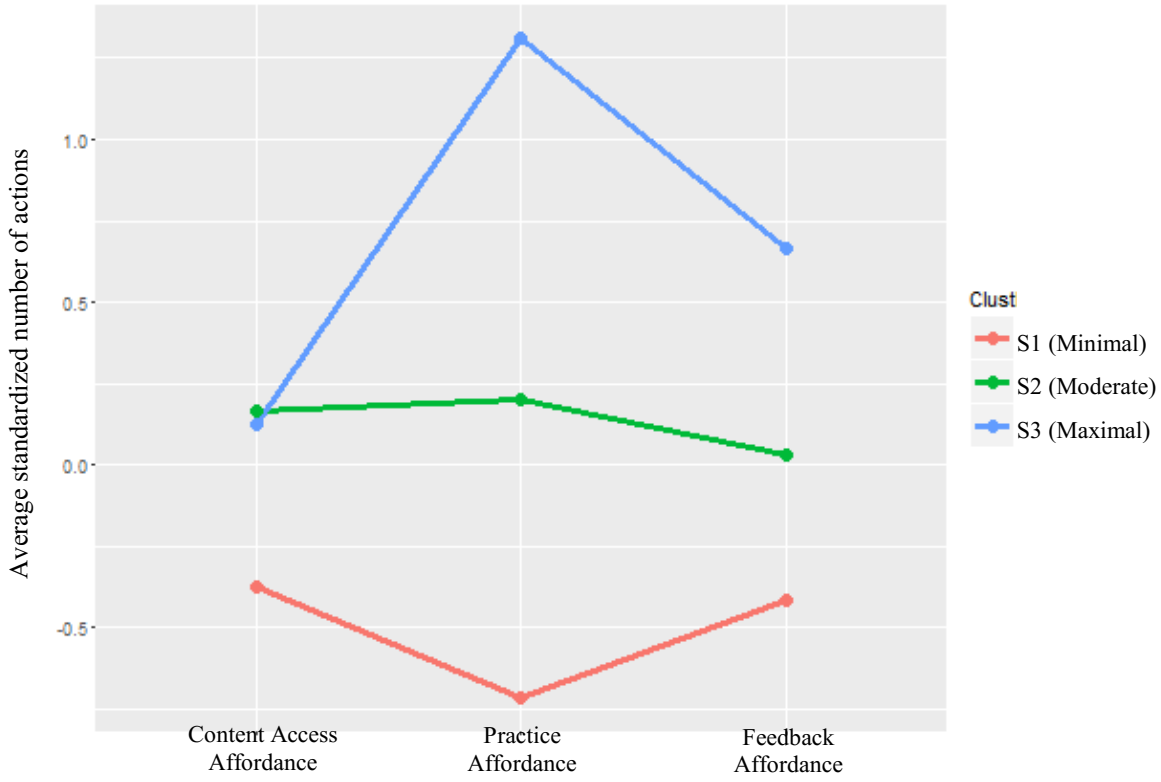

Figure 2-4. Average standardized affordance actualizations (log data)

Table 2-4. ANOVA results for mean difference in affordance actualizations (log data)

Affordance Actualization	Minimal (S1)	Moderate (S2)	Maximal (S3)	F	P-value
Content Access	226.3	305.8	300.4	21.32	.000***
Practice	75.3	402.7	800.8	824.30	.000***
Feedback	24.3	44.8	73.7	44.48	.000***

Sample size: 310. * means p-value < 0.100; ** means < 0.050; *** means < 0.010

Table 2-5. Tukey HSD test results for mean comparisons of affordance actualizations (log data)

Affordance Actualization	Cluster (I)	Cluster (J)	Mean Difference (I-J)	Std. Error	P-value
Content Access	Minimal	Moderate	**-79.453**	**12.718**	**.000*** **
		Maximal	**-74.044**	**21.102**	**.001*** **
	Moderate	Maximal	5.409	21.509	.966
Practice	Minimal	Moderate	**-327.407**	**12.030**	**.000*** **
		Maximal	**-725.438**	**19.961**	**.000*** **
	Moderate	Maximal	**-398.031**	**20.346**	**.000*** **
Feedback	Minimal	Moderate	**-20.417**	**3.439**	**.000*** **
		Maximal	**-49.398**	**5.707**	**.000*** **
	Moderate	Maximal	**-28.981**	**5.817**	**.000*** **

Sample size: 310. * means p-value < 0.100; ** means < 0.050; *** means < 0.010

Step 4. Evaluate the Species' Sensemaking and Characteristics

After measuring all three major components of our ecological framework (affordance perceptions, their characteristics and the technoniches), we turned to evaluating how the three species are different in terms of their sensemaking and characteristics. Figure 2-5 depicts the average affordance perceptions for each species. We used ANOVA to test if the three clusters (species) demonstrated different perceptions of the three affordances. Table 2-6 shows that the three clusters showed some difference in two of the three affordance perceptions based on p-values of the F statistic at the 0.05 level of significance. Two-by-two comparisons using the Tukey HSD test provided more details (see Table 2-7). Specifically, S1 (Minimal) and S3

(Maximal) species perceived the Practice and Feedback affordances at significantly different levels that were consistent with their actualization of those affordances. S1 (Minimal) and S2 (Moderate) species perceived the Practice affordance at different levels consistent with their affordance actualizations. None of the species were differentiated on the Content Access affordance perceptions.

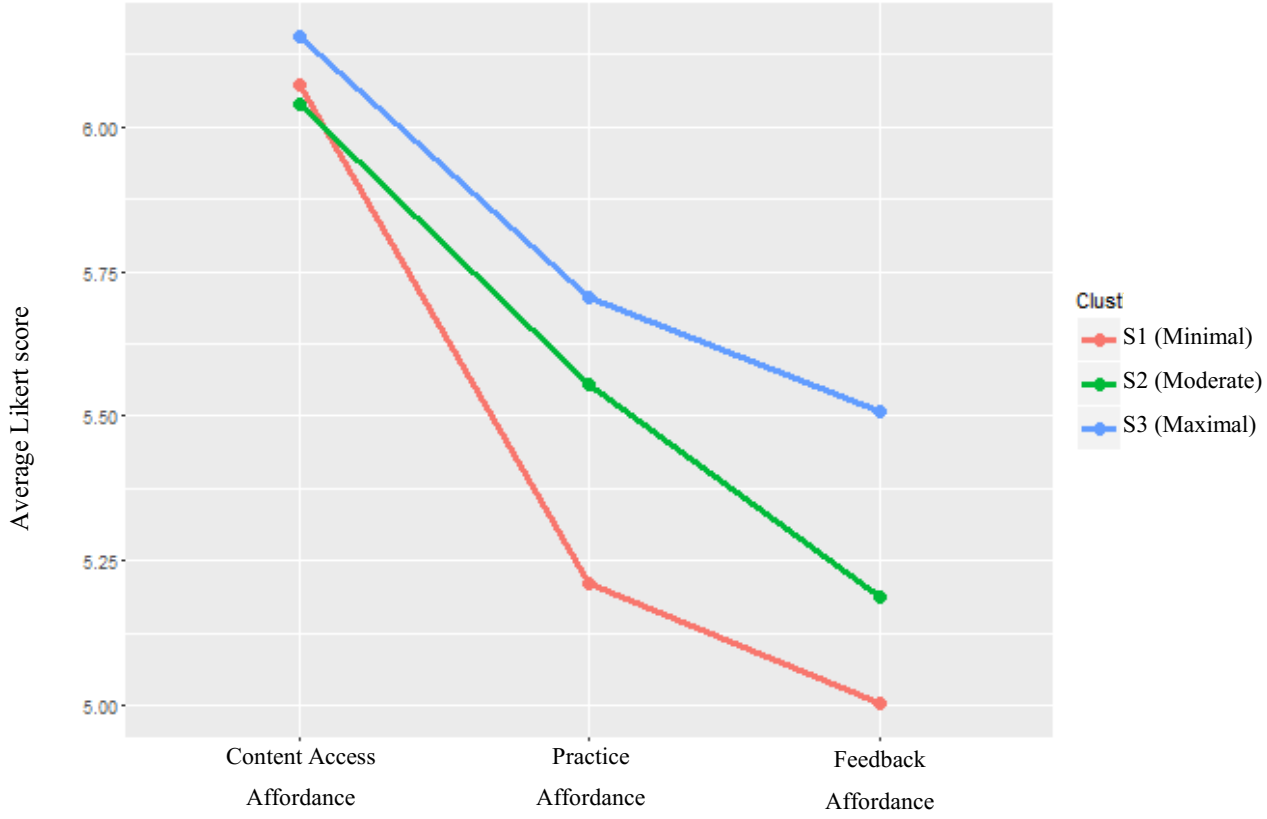

Figure 2-5. Average affordance perceptions (survey responses)

Table 2-6. ANOVA results for mean difference in affordance perceptions (survey data)

Affordance Perception	Minimal (Mean)	Moderate (Mean)	Maximal (Mean)	F	P-value
Content Access	6.07	6.04	6.18	0.562	.571
Practice	5.21	5.56	5.74	5.690	.004***
Feedback	5.00	5.19	5.51	4.376	.013**

Sample size: 310. * means p-value < 0.100; ** means < 0.050; *** means < 0.010

Table 2-7. Tukey HSD test results for mean comparisons of affordance perceptions (survey data)

Affordance Perception	(I) Cluster	(J) Cluster	Mean Difference (I-J)	Std. Error	P-value
Content Access	Minimal	Moderate	0.03	0.081	.903
		Maximal	-0.11	0.134	.693
	Moderate	Maximal	-0.14	0.137	.542
Practice	Minimal	Moderate	**-0.35**	**0.124**	**.016****
		Maximal	**-0.53**	**0.206**	**.028****
	Moderate	Maximal	-0.19	0.210	.651
Feedback	Minimal	Moderate	-0.19	0.109	.206
		Maximal	**-0.50**	**0.181**	**.015****
	Moderate	Maximal	-0.32	0.184	.196

Sample size: 310. * means p-value < 0.100; ** means < 0.050; *** means < 0.010

Next, we examined the three species in terms of their user characteristics. In other words, we investigated if any of the characteristics significantly differentiated the three species. We first used ANOVA to see if the three species were different in any of the learning styles we studied (see Table 2-8). The null hypothesis of equality of the means of the three species was rejected only for the Visual learning style. The Tukey HSD test provided the two-by-two mean comparisons for the Visual learning style (see Table 2-9). Specifically, the only difference in learning styles was that the S1 (Minimal) user species had a significantly higher incidence of the Visual learning style than the S2 (Moderate).

Table 2-8. ANOVA results for mean differences in learning styles (survey data)

Learning Style	Minimal (Mean)	Moderate (Mean)	Maximal (Mean)	F	P-value
Active	-0.09	0.14	-0.47	.547	.579
Sensing	1.98	2.20	2.80	.365	.694
Visual	2.51	1.52	1.67	5.062	.007***
Sequential	0.93	1.22	1.27	.722	.487

Sample size: 310. * means p-value < 0.100; ** means < 0.050; *** means < 0.010

Table 2-9. Tukey HSD test results for mean comparisons of Visual learning style (survey data)

Learning Style	(I) Cluster	(J) Cluster	Mean Difference (I-J)	Std. Error	P-value
Visual	Minimal	Moderate	**0.99**	**0.326**	**.007*** **
		Maximal	0.84	0.541	.265
	Moderate	Maximal	-0.15	0.551	.962

Sample size: 310. * means p-value < 0.100; ** means < 0.050; *** means < 0.010

Then, we used contingency tables with standardized residuals to examine the three species in terms of their four other characteristics: age, gender, major and experience with Moodle (see Appendix 2-10). The standard residuals for all cells of all contingency tables were less than 1.96 (which represents the 0.05 confidence level), so there was no reason to believe that any differences in age, gender, major or experience directly affected the species we identified. However, we suspect that gender may have an indirect effect on the species through the Visual learning style. This is consistent with research that has found that whereas males tend to prefer visual learning, females tend to be more verbal learners (Eiszler 1983).

We used the SPSS PROCESS macro (Hayes 2013) to test if gender had a mediated effect on the species through Visual learning style. Contrary to the traditional understanding that a mediated effect may not exist unless there is a direct effect, Hayes (2009) argues that such an assumption is not valid and that a mediated effect can be examined independently of a direct effect. Appendix 2-11 presents the results of the mediation analysis. It demonstrates that gender is directly related to the Visual learning style (beta=0.9341, p-value=0.0028) with male users having a tendency for the Visual learning style. Moreover, the Visual learning style is related to the species (beta=-0.0341, p-value=0.0137). The indirect effect of gender on the species is meaningfully different from zero (beta=-0.0319, SE=0.0178, CI=-0.070 to -0.009). Although the size of the indirect effect of the gender is small, it could still be considered one way of meaningfully influencing the species of Moodle users.

DISCUSSION

Examining the results from the empirical analysis of Moodle user species, their technoniche, sensemaking and characteristics, we have obtained some valuable insights about ecological analysis of technological ecosystems in general, and also of the specific implementation of Moodle that we investigated.

First and foremost, it is essential to understand that not all the major affordances of an information system would necessarily be part of the technoniche for the user population. Two types of resources may be excluded from the ecological analysis of a technological ecosystem: a) abandoned resources and b) mandatory resources. Technological resources may be abandoned for a variety of reasons related to the design of the system, its alignment with user goals, and the social context of use. In the ecological analysis of the specific Moodle instance we studied, the three species actualized the Communication affordance at similarly low levels with an average of 6, 8, and 9 actions for the entire semester for the three species (see Appendix 2-7). It would be safe to say that the Communication affordance was abandoned by the users, so it does not differentiate the three species and plays no role in Moodle user speciation; therefore, the Communication affordance is excluded from Moodle users' technoniche. This is consistent with the evidence from the interview data attesting that users normally use social media like Facebook and WhatsApp for course-related communications rather than Moodle's communication features.

Mandatory resources would not be considered part of the technoniche for two reasons. For one, they would be actualized at similar levels because their actions are required, and thus the level of actions would be unable to differentiate the user species. The other reason is that even if they were required at different levels for various users, their use would not be reflected in users' perception and sensemaking of the technology. This is consistent with evidence that the relation between users' beliefs and perceptions and their intention to act does not hold in settings where technology use is mandatory (Venkatesh et al. 2003; Wu and Lederer 2009). In the empirical evaluation of our specific Moodle implementation, the Submission affordance was actualized at somewhat different levels by some of the species, but it was not perceived differently by any them (see Appendix 2-7). This could be explained by the mandatory nature of the Submission affordance, which disrupts the relation between species' technoniche and their sensemaking;

since submission is required for students to earn their course grade, they have to actualize it no matter what their perceptions and preferences might be. Therefore, we removed Submission as a differentiating criterion of the species' technoniches when analyzing their sensemaking of Moodle.

A second major insight is that the three user species are not mere representations of three levels of Moodle usage, but that they demonstrate three distinct patterns of user sensemaking of Moodle explained by some of the users' preferences and characteristics. Figure 2-6 demonstrates sensemaking of the three species based on the levels of their affordance perceptions and how they are different in some of the user characteristics. Minimal users perceived Moodle mostly as a place to access content. Moderate users understood Moodle as a place in which they could access content and also practice what they had learned. Maximal users understood Moodle as a platform to access content, practice and get feedback about their progress in the course. While the three species actualized the three affordances at significantly different levels, some of their characteristics seemed to play a role in how they adapted to their technoniche. In terms of their learning styles, users with highly visual styles tended to adapt minimally to the Moodle environment. This could be indicative of the highly textual, rather than visual, environment of the Moodle implementation that we studied. Moreover, while users' gender barely played a direct role in shaping the three species, it played a small but significant indirect role through the Visual learning style in shaping the three species. In other words, male users tended to be more visual, which made them more inclined to actualize Moodle minimally, while female users tended to be less visual and more verbal which made them more inclined to actualize Moodle at higher levels.

Species	Content Access	Practice	Feedback	Learning Style	Gender (indirect
Maximal	High	High	High		Female
Moderate	High	High	Low		
Minimal	High	Low	Low	Visual	Male

Level of perception (on a 7-point Likert scale): High: 5.5 to 7 Low: 4 to 5.5

Figure 2-6. Sensemaking of the three species and their characteristics

The third major insight from the empirical analysis is that the reflection of species' technoniche in their sensemaking depends on the level of actualization of the affordances. When an affordance is actualized at high levels, even though it may be used at significantly different levels, such a difference may not translate into a different kind of sensemaking. For instance, the Content Access affordance was actualized at very high but significantly different levels by the three species; however, it was perceived at very high and similar levels by the three species. This may be explained by the fact that the repetitive actions get automatic and less conscious after a while, so further actualization of the affordance may not necessarily be reflected in their perception and sensemaking of the new technology (Ortiz de Guinea and Markus 2009). There is other evidence in our results that support such an understanding. For instance, the Practice affordance is both actualized and perceived at different levels by the Minimal and Moderate species, who actualize Practice affordance at lower levels. At the same time, it is actualized differently but perceived similarly by the Moderate and Maximal species, who actualize Practice affordance at high levels.

In sum, the two ETS propositions provide fruitful insights on how the Moodle features that the users employed play a role in user sensemaking of the system. The first proposition suggests that the three user species are related to how the users make sense of the system. The Minimal users made sense of Moodle mainly as a provider of course material; the Moderate users further

understood Moodle as the venue for practising for exams; and the Maximal users' pattern was consistent with perceiving Moodle as a content, practice, and feedback provider. The second proposition suggests that certain user preferences and characteristics contribute to shaping the three species. Users with a Visual learning style tended to adapt to the Moodle implementation that we studied as Minimal users because it provides poor support for visual features and interactivity. In addition, gender played a subtle role in shaping the three Moodle species through the Visual learning style. This mediated impact of gender and the direct role of the Visual learning style are important dynamics that underlie user speciation and sensemaking of Moodle that only the ecological approach was able to reveal.

CONCLUSION

To address the missing role of the IT artifact in user sensemaking of technology, this essay has provided an ecological framework that analyzes user species' sensemaking of technology in relation to their technoniche and personal characteristics. It proposes appropriate methodological tools for ecological analysis of technological ecosystems. Moreover, it empirically illustrates the applicability of the proposed approach and methodology with fruitful insights from analyzing users' sensemaking of the focal implementation of Moodle in a real-life scenario. The empirical study identified five major Moodle affordances, including Content Access, Submission, Communication, Practice, and Feedback. Analysis of user log data identified three species (Minimal, Moderate, and Maximal users) that adapt to distinct technoniches consisting of three of the five affordances: Content Access, Practice, and Feedback. Submission and Communication affordances were excluded from the species' technoniche because of their mandatory use or their abandonment by the users, respectively, which resulted in their inability to differentiate the species. While Minimal users perceived Moodle primarily for its Content Access capabilities, the Moderate users came to see Moodle as a place not only to access content but also to practise their knowledge. Consistent with their technoniche, Maximalist users tended to make sense of Moodle as a place to access content, practise their knowledge, and acquire feedback on their progress. Users' Visual learning style played a role in Moodle user speciation. The users with the highest visual learning scores tended to adapt to Moodle minimally. Moreover, gender indirectly affected the speciation: male users tended to be more visual learners than verbal learners, and the visual learners tended to adapt Moodle as Minimalists.

There are two major contributions of this study. First, it adds to the IS adaptation research (Barki et al. 2007; Ortiz de Guinea and Webster 2013; Sun 2012) and extends the current cognitive and social approaches to technology sensemaking by relating user sensemaking of technology to the technological artifact. This allows scholars to open the black-box of technology sensemaking and explain not only in what major ways users make sense of technology, but also how their sensemaking is shaped in relation to the users' technoniches and their personal characteristics. Second, this study extends IS research by proposing valuable conceptual and methodological tools that enable scholars to examine users and the technological artifact in relation to each other. It identifies homogenous groups of users (species) on the basis of their adaptation to the same technological configurations (technoniches). This provides an alternative to deterministic inquiries about user adaptation to technology features. The concepts suggest a new way to analyze patterns of user adaptation to technology, and we provide the tools for doing so.

The present study has a few limitations. First, the purpose of this study is not to produce universally generalizable empirical findings for the Moodle ecosystem, but to provide an ecological framework and the required methodological tools that can be applied to various empirical contexts. Thus, caution must be exercised in attempting to generalize these results. For instance, while the current findings would be generalizable to courses and Moodle implementations designed and conducted in a similar fashion to our focal setting, it would not be well generalizable to other types of classes and Moodle implementations or to other learning management systems. A second limitation is that the applicability of our methodological approach is heavily dependent on the availability of appropriate interview, survey and computer usage log data. For instance, the methodology would be difficult to apply to new systems design and development when there are no existing users and no available log data. A third, statistical limitation concerns the reduction of the Index of Learning Style questionnaire using MTurk data. Because some of the items in the reduced scale had a different variance from the full scale, it cannot be considered a perfect scale reduction. However, as the mean differences in the scales were statistically insignificant, we consider that analysis nonetheless acceptable.

This study has important implications for research. Using the ecological approach and its methodological tools, researchers can go beyond the use/not-use dichotomy and examine the patterns of user adaptation to the technology artifact and how such patterns change and evolve

and thus bring about consequences for organizations. In addition, this study highlights the theoretical link between users' sensemaking of new technology and their adaptation to the material artifact. The innovative combination of interviews, card sorting, surveys and cluster analysis to relate user actions to affordances provides a helpful way to quantify affordance actualizations and study users' adaptive behaviour as it unfolds. The analysis of survey data at the level of user species, which is identified by analysis of user log data, provides a unique way of analyzing user sensemaking in relation to users' adaptation to technology. The specific combination of research methods suggested to examine the ecological approach sets an example for the design of research methods that capture the essence of the theoretical meaning in IS theorization (Bagozzi 2011). Moreover, whereas the dominant cognitive approach to technology sensemaking contributes to the structurational technology research, the suggested ecological approach adds to the recently growing body of research that adopts a critical realist approach to IS research. The technology affordances would represent the generative mechanisms of the critical realist perspective that are the "causal structures that generate observable events" (Henfridsson and Bygstad 2013, p. 911). While the cognitive approach does not adequately explain the causal structures that produce technological consequences, the suggested ecological approach theorizes how affordances shape user sensemaking and adaptation to technology.

This study also has a number of practical implications. System development teams can use the proposed methodology to bring insight on how to support sensemaking of the technology. For instance, our ecological analysis of a Moodle ecosystem explains the distinct adaptation of the users who understand Moodle as a place for content access and practice (Moderate users) in terms of the exact features they use and the level of their dependency on these features. Such sensemaking of Moodle may be supported by facilitating use of the related features together. Moreover, system designers could help evolve the users to a higher level of adaptation (Maximalists) by enclosing and further integrating the feedback features with the practice ones. "Evolution" in this context is according to the ecological species concept, which means helping users to change their patterns of IT resource utilization in a way that might have better performance outcomes.

Another implication is that technology managers could use the insights from such ecological analysis to facilitate user adaptation to new technology. For instance, Content Access is the

common meaning of Moodle among all user species; therefore, any instructor using Moodle needs to make sure that everyone understands various ways to access content on Moodle though folders, links, documents, etc. If the instructors want to enhance use, the next step would be to train students on how to use practice affordances, and then further on how to use the feedback provided. Instructors could also enhance use by incorporating feedback in every assignment or practice quiz available on Moodle so that Moderate users would be encouraged to enhance their practice to Maximal use of the system.

Future research may complement the current study in several ways. First, future work could build further understanding about the concepts of user species and their technoniches. Here we suggest one way to conceptualize and operationalize these concepts in IS research based on resource dependency and use; other conceptualizations or new operationalizations using various clustering techniques and distance measures might enhance our understanding of the concepts and extend their usefulness. Second, the concepts of technoniches and user species could be used to understand the organizational impact of new information systems at the species level of analysis; that is, researchers could examine how various species perform differently in organizations. It would be very interesting to see if various species and their technoniches bring about different consequences. Third, the two concepts lend themselves very well to longitudinal inquiries on how system use evolves and changes through time. They can provide useful tools for analysis of the evolution of user behaviour.

Transition to Essay 3

This thesis addresses the role of the IT artifact in various phases of user-technology interaction. The first two essays in this thesis deal with the role of the IT artifact in the early phase, that is, user sensemaking of technology, through an ecological approach. The third essay focuses on the role of the IT artifact in the later phase of user-technology interaction, that is, user adaptation to technology. It draws on the ecological ideas from the first two essays to propose a new technique for analyzing the patterns of user adaptation to the IT artifact where these patterns form the basis for creating user personas and contribute to the user-centred design of technology.

The third essay draws on affordance theory and proposes analyzing user actions in the context of the affordances that they actualize. Instead of creating personas by using the patterns in user actions, this essay suggests creating them by using the patterns of affordances actualized by users. The new approach addresses the limitations of the current qualitative and quantitative techniques for persona creation by using qualitative insights (affordances extracted from interviews and card-sorting of actions to affordances) and quantitative analysis (cluster analysis of user log data) to identify the behavioural patterns and to create the user personas. The resulting personas would be contextually rich and representative of the user community. Moreover, the third essay illustrates the proposed technique by empirically creating personas of users of a real system, and it compares the resulting personas with quantitative and qualitative personas created using current techniques.

The third essay focuses on the later phase of user-technology interaction, that is, user adaptation to technology. It proposes affordance actualization as a new level of analysis for examining patterns in user behaviour in relation to the IT artifact and for creating user personas for the user-centred design of new technologies.

Essay 3: Affordance-Based User Personas: A Mixed-Methods Approach to Persona Development

ABSTRACT

During the last decade, the persona technique has been used in interface design practices to put user needs and preferences at the centre of all development decisions. Persona development teams draw on qualitative data, quantitative data or a combination of both to develop personas that are representative of the target users. Despite the benefits of both approaches, qualitative methods are mostly limited by the cognitive capabilities of the experts, whereas quantitative methods lack contextual richness. To gain the advantages of both approaches, this paper suggests a mixed qualitative-quantitative approach to create user personas based on the patterns of the affordances they actualize rather than merely the actions they take. It enriches personas by referring to the purposes fulfilled through affordance actualizations, and it grounds personas in readily available objective log data. This study illustrates the practical value of the proposed methodology by empirically creating personas based on real user data. It also creates quantitative-only personas, presents independently developed qualitative-only personas, and compares them to the affordance-based personas to demonstrate the advantages of the suggested method.

Keywords: Personas, affordances, mixed qualitative and quantitative methods, interview, card sorting, cluster analysis.

An earlier version of this essay was presented as: Mesgari, Mostafa, Chitu Okoli and Ana Ortiz de Guinea (2015). Affordance-based User Personas: A Mixed-Method Approach to Persona Development. Proceedings of the 21st Americas Conference on Information Systems. *Puerto Rico. August 13-15, 2015.*

INTRODUCTION

Personas have been part of Human-Computer Interaction (HCI) and User-Centred Design practice and research for more than a decade (Adlin et al. 2006; Gulliksen et al. 2003; Miaskiewicz et al. 2009). Personas are characterizations of the target user group for which the system is being designed. A persona is a "precise description of a user's characteristics and what he/she wants to accomplish" (Chang et al. 2008, p. 439). Persona Development Teams usually draw on either qualitative or quantitative data to understand users and develop representative personas (Brickey et al. 2010; Faily and Flechais 2011). While both qualitative and quantitative methodologies appear to have benefits, each method alone has its own limitations. Qualitative methods are criticized for being limited to the cognitive capabilities of the development team (Laporte et al. 2012), and quantitative methods lack context and richness (Brickey et al. 2012).

To address the issue, this paper draws on the theory of affordances to suggest a mixed qualitative-quantitative approach to the identification of personas based on patterns of affordance actualization and major user behaviours. It qualitatively identifies the system affordances and the actions actualizing those affordances and then quantitatively identifies major patterns of affordance actualization in user log data. This study contributes to User-Centred Design practice and research by proposing a methodology to create richer and more credible personas. It bridges the behavioural IS research and the design-oriented HCI research to bring fruitful insights for both. For IS research, this study provides a way to analyze user behaviour in relation to the IT artifact. For HCI research, it suggests analyzing user action data at a more behavioural level in terms of the affordances that users actualize.

To demonstrate the practical value of the suggested methodology, we empirically examine student use of Moodle, a learning management system, in a North American business school and identify three personas that demonstrate unique patterns of affordance actualization. The student sample represents the actual professional user population for this study; it is not a substitute for some other user population. Moreover, this study does not intend to generalize the findings over and above the specific implementation of the system studied. To demonstrate the advantages of the proposed method, we use our empirical data to create quantitative-only personas, and we

draw on independently developed qualitative-only personas. We compare the affordance-based personas to the other two and thoroughly discuss the implications for research and practice.

DEVELOPING USER PERSONAS

Alan Cooper (1999) first suggested the notion of user personas. Since then, personas have become an important technique to put users at the centre of every system development project and make the resulting system more user friendly (Johansson and Messeter 2005; Long 2009; Pruitt and Grudin 2003). Personas give the development team a better idea of who the target users are, what they need, and what they use the system to do (Chang et al. 2008). A persona is an "archetypical representation of customers or users" (Broschinsky and Baker 2008, p. 545). It is a fictional character that puts a face on a coherent user data structure through which the system development team can communicate and build a shared understanding of user characteristics, needs and behaviours. Furthermore, personas can effectively engage team members in the system development process (Ma and LeRouge 2007; Pruitt and Grudin 2003). The user data represented by personas may refer to either user demographics (e.g. age, occupation and education), psychographics (e.g. lifestyle, goals, needs and intentions), or user behaviour. Various qualitative and quantitative methods draw on these user data to create representative user personas. As an illustration, Table 3-1 represents the personas that Microsoft created for Office 365 Enterprise application users.

Table 3-1. Microsoft Office 365 Enterprise personas

Persona Name	Description
Transforming	• Customers with propensity to increase/decrease employee count regularly • Require agile scalability and flexibility • E.g. acquisitions, layoffs, temporary seasonal workers
Cost Saver	• Customer primarily looking to cut costs, value a focus on TCO • Interested in moving from capex to opex
Google Compete	• Customer in active discussions with Google • Greater focus on collaboration and messaging workloads
Task Worker	• Population of structured task workers who don't have dedicated PCs • Prevalent in retail, hospitality, manufacturing and healthcare industries • E.g. Manufacturing Plant Floor worker, Nurse, Barista
Dated Environment	• Customers on older versions (N-2+) of Exchange, SharePoint and Office who don't have new version rights • Want to adopt new business productivity capabilities and stay current

	• E.g. Customer deployed on Exchange 2003 without Software Assurance

Personas copied from Columbus (2013)

Qualitative approaches to persona development are mainly dependent on interviews and observational data referring to user psychographics. Specific approaches include ethnography (Broschinsky and Baker 2008; Johansson and Messeter 2005), grounded theory (Faily and Flechais 2011), affinity diagrams (Broschinsky and Baker 2008; Lindgren et al. 2007; Pruitt and Grudin 2003), expert panels (Lindgren et al. 2007) and latent semantic analysis (Brickey et al. 2010; Miaskiewicz et al. 2008). These methodologies are popular because of the rich contextual information they provide about users and their actions.

Quantitative approaches draw mainly on user surveys and computer log data referring to user demographics or user actions and behaviours. They include multivariate data analysis techniques that are used to find trends in data and identify homogenous groups of users as the bases for the personas. Some popular quantitative analysis methods are factor analysis (McGinn and Kotamraju 2008), principal component analysis (Brickey et al. 2010; Sinha 2003), cluster analysis (Brickey et al. 2010; Moser et al. 2011; Rahimi and Cleland-Huang 2014), correspondence analysis (Laporte et al. 2012) and association rule mining (Rahimi and Cleland-Huang 2014). The main advantage of quantitative methods is to build personas based on information about large numbers of users believed to be representative of the user target population (Brickey et al. 2010). Moreover, quantitative personas are well grounded in user data, which makes it easy to communicate the personas to a development team because they are easily traceable to user data (Broschinsky and Baker 2008).

Despite the respective benefits of the qualitative and quantitative methodologies, each method alone has certain limitations. For example, the quantitatively developed personas based on user actions and log data have been criticized for excluding the context and the users' preferences and motivations. They focus on users' actions without taking into consideration that actions occur within the context of users' intentions and goals. On the other hand, although qualitative persona development methods are richer in terms of context, they take much more time and resources to develop (McGinn and Kotamraju 2008). Moreover, qualitative methods require a considerable effort in induction from specific and context rich users' information to an abstract representation

of a persona. Thus, they are criticized for a potential lack of credibility and rigour (Laporte et al. 2012).

Table 3-2. Existing approaches and methodologies for persona creation

Approaches	Methodologies	Advantages	Disadvantages
Quantitative	• Factor analysis • Principal component analysis • Cluster analysis • Correspondence analysis • Association rule mining	• Grounded in data from large user community • Easy to explain	• Lack of contextual richness
Qualitative	• Ethnography • Grounded theory • Affinity diagrams • Expert panels • Latent semantic analysis	• Rich contextual information	• Potential lack of credibility and rigour • Take very much time and many resources to develop • Quality is inconsistent across different persona designers
Mixed Quantitative and Qualitative	• Creating groups of users quantitatively and adding richness to those groups qualitatively	• Grounded in data from large user community • Rich contextual information	• Groups are made based solely on quantitative data • Do not leverage the full potential of qualitative data

The limitations of using each method alone have encouraged some scholars to combine quantitative and qualitative methodologies together (e.g. McGinn and Kotamraju 2008; Moser et al. 2011; Sinha 2003). Mixed-methods approaches help to overcome the weakness of any single method by compensating one with the strengths of another (Jick 1979). However, the existing attempts do not seem to realize the full advantages of a mixed-methods approach to identify user personas. They typically group users into personas only on the basis of quantitative data and then use qualitative data to add narratives and enrich persona descriptions. In other words, they do not use qualitative data for identifying the personas, but rather for enriching them after the personas have already been identified quantitatively. Table 3-2 summarizes the advantages and disadvantages of the three approaches to persona creation.

In the following sections, we suggest a mixed-methods approach that uses both qualitative and quantitative data to group users and identify personas on the basis of their affordance actualization patterns.

CREATING USER PERSONAS BASED ON AFFORDANCES

The theory of affordances (Gibson 1977) explains individual behaviour in terms of affordances, defined as the "action possibilities" provided by the environment to an individual. They are functional properties of the individual-environment system (Hutchby 2001). "Functional" means that affordances refer to some activity, purpose or task; they are not merely actions. Affordances are the roots of individual perceptions and actions. People choose to actualize affordances through actions embedded in the realm of their intentions and purposes.

Affordance theory has been adapted to various areas of technology-organization research (Majchrzak et al. 2013; Mesgari and Azad 2013; Mesgari and Okoli 2015; Zammuto et al. 2007). Drawing on this theory, we suggest creating personas based on affordance actualization patterns grounded in users' intentions and purposes, rather than on an exclusive focus on users' actions. What guides users' behaviours is the affordances they perceive and thus actualize on the basis of their direct actions, intentions and purposes. That is, actions do not occur in a vacuum, but within the individual-environment context. In other words, users interact with the system and actualize affordances that are based on the goals they want to attain. Thus, actions occur in context. This approach overcomes the limitation of simply analyzing users' actions without understanding the intended purposes of those actions.

We propose examining user behaviour at the affordance level of analysis and grouping them according to the pattern of affordances they actualize. That is, instead of clustering users on the basis of their action data, we first aggregate various actions into their related affordances and then cluster the users according to the affordances they have actualized. Clusters based on affordance actualizations address the limitation of overlooking information about users' intentions and goals, which is a problem with clusters that are based on actions alone. While current methods like factor analysis identify user actions based on statistical correlations and produce clusters that are difficult to interpret, the proposed method aggregates user actions based

on data-driven, meaningful affordances. Thus, we believe that our methodology would be advantageous over strictly statistical methods.

In this approach, we extract major affordances by qualitatively analyzing in-depth interviews with users. Next, we use the card sorting technique to categorize users' actions into affordances. Finally, we cluster users according to the affordances they actualize, rather than merely according to the actions they take. The proposed method uses both qualitative and quantitative data to develop personas based on specific system affordance actualization patterns. The following subsections describe this approach in detail.

Extracting Affordances

Affordances are action possibilities that guide user behaviour. As explained earlier, because they are functional properties of the technological environment that supports users' purposes and tasks (Michaels 2003), they put actions within the context of users' purposes. Thus, whereas actions in themselves do not necessarily indicate any specific purpose, by definition affordances encompass the users' purposes and motives when interacting with a system. For instance, "sitting down" as an action makes no reference to the individual's purpose. In contrast, the affordance "taking a rest" includes the purpose fulfilled by an individual when sitting on a chair. It is important to note that technology affordances refer only to those affordances related to the focal technology itself, not to the "complete" set of affordances of the environment.

To empirically extract the affordances of a new system, it is suggested to draw on users who are well experienced with the technological domain (Heft 2003). Because affordances are functional in nature, it is important to draw upon users who have experience with the technical environment as well as the social context in which the use of a system takes place. Qualitative analysis of rich interview data with experienced users is the main technique used to extract affordances of new technological settings (Mesgari and Faraj 2012; Strong et al. 2014). Depending on the extensiveness of the system, a few in-depth interviews with experienced users is usually sufficient to detect most important system affordances. To extract affordances, interview data needs to be qualitatively coded to identify tasks, activities and purposes. The coded data is then grouped into meaningful affordances. When affordances are identified, they need to be clearly

defined so that they can be easily differentiated from each other. Clear definition of affordances is the key to the next step for identifying the actions that actualize the affordances.

Identifying Actions That Actualize Affordances

In the next step, we first need to prepare a list of actions available to the user. Typically, this can be obtained from user log data. Each action should then be clearly defined so that anyone reading the action definitions would have the same understanding of what each action refers to.

Next, a few experienced users can be recruited to identify which actions actualize which affordances through multiple rounds of a card sorting exercise (Moore and Benbasat 1991). These users are provided with a list of actions (obtained from user logs) and a list of affordances (obtained from in-depth interviews), and they are asked to imagine which affordance they are actualizing when they take any of the specific actions. Around five experienced users should be sufficient for each round of the card sorting exercise (Moore and Benbasat 1991). Inter-rater reliability measures, such as Fleiss' kappa (Fleiss 1971; Fleiss et al. 1979), would be used to demonstrate the degree of agreement among users about which action actualizes which affordance.

In many cases, the first round of card sorting would highlight disagreements on specific actions and affordances. The researchers would need to examine the conflicting items to understand the reasons for disagreement. They may ask the users to explain their categorization, and this will help the researchers to improve their identification and definition of actions and affordances. They should repeat the card sorting exercise with new sets of experienced users until they reach acceptable agreement on the set of actions that actualize each of the affordances. While there is no concrete consensus, most guidelines consider a kappa of 0.65 to indicate substantial agreement among raters (Landis and Koch 1977; Moore and Benbasat 1991).

Creating Personas by Identifying Patterns of Affordance Actualization

In the third step, the user log data is examined, user actions are aggregated into the affordances they actualize, and a statistical clustering technique is applied to identify user groups based on their patterns of affordance actualization.

The specific choice of clustering method and distance measure is highly dependent on the goals of the study; it can significantly change the user grouping results and the personas created. To select the best distance measure, the researcher needs to decide: Should users be grouped according to their *level of affordance actualization* or according to the *pattern of affordance actualization*? In other words, should users with similar levels of affordance actualization form a persona, or should users with similar proportional affordance actualizations? In the former case, using Euclidean distance would be preferable; but in the latter case, the Pearson correlation distance would be advised.

To illustrate this proposed methodology, we follow with a complete empirical demonstration.

MOODLE USER PERSONAS

Moodle is a free and open-source learning management system that is actively developed by Moodle HQ and a large community of volunteer contributors. As of May 2016, there were over 75,000 Moodle sites in 225 countries, running over 9 million courses for more than 85 million users.[2] Whereas Moodle defines certain user "roles" (e.g. Student, Teacher and Teaching Assistant), these roles are essentially user privilege profiles. They do not attempt to accommodate how users with the same role might possibly use their privileges in significantly different ways—which is the focus of personas in this study.

To demonstrate the applicability of the proposed persona development methodology and to help the Moodle community to improve their design and development, we employ the suggested affordance-based mixed-methods technique to create the user personas representative of a sample community of Moodle users. According to the guidelines provided by Compeau et al. (2012), the use of a student sample is ideally suitable for this study for two reasons. First, the student sample is not used as a proxy for some professional user group, but it represents the actual user group for the purposefully chosen system of this study (i.e. Moodle). Second, this study does not aim to generalize the findings over and above the specific implementation of the system examined. In fact, the purpose of the empirical inquiry is to illustrate the practicality of the suggested method and the value of the insights derived from it. The sample is drawn from

[2] https://moodle.net/stats/

students in a North American business school with over 9,000 students that is currently in the process of switching from FirstClass to Moodle as its official learning management system. Creating Moodle user personas could help guide instructors in the school to design their Moodle pages to support major personas. Moreover, the Moodle community may obtain insights on how certain implementations of Moodle guide users' behaviour.

In February 2015, we conducted a pilot study to evaluate Moodle user personas. We interviewed five users to identify the major affordances and ran two rounds of card sorting to relate user actions to the affordances. Users' log data was collected and analyzed to identify the distinct user personas of Moodle. The pilot study is fully reported by Mesgari et al. (2015), and the methodological detail is copied in Appendix 3-1 for further information.

We conducted the full study from July to December 2015. We conducted 12 more interviews with experienced student users of Moodle to identify the major affordances provided by Moodle to the student community. Next, we conducted two rounds of the card sorting technique to assign user actions to the identified affordances. Then we used cluster analysis to analyze the student log data to find the patterns in student behaviour and how they actualize various Moodle affordances relative to each other. The identified clusters can form the basis for creating the user personas for the Moodle developer community.

Interviews: Identifying Affordances in Moodle

To empirically extract the affordances of a new setting, users should be consulted who are well experienced with the technological domain (Heft 2003; Mesgari and Faraj 2012). Since affordances have social aspects, understanding them requires consulting those who have extensive experience with the technical environment as well as the social context in which the technology is used. This step of the study was also used to generate data for a distinct but somewhat related study (see Essay 2); what follows is a detailed description of the procedure we followed and the results.

To recruit experienced users, we invited about 400 undergraduate students of a North American university by email to register for an interview session about their experiences with Moodle if they had completed at least two courses that used Moodle. We offered a $15 compensation to participants for their time. 43 students registered to participate in the study by filling in a form

that explained the nature and extent of their experience. 12 of their most experienced ones were contacted to schedule an interview. They were interviewed on five consecutive days in July 2015. Interviews were audio recorded and took from 30 to 50 minutes each. We added the 5 other interviews conducted during the pilot study conducted in February 2015 to the collection of the qualitative data. Appendix 3-2 displays various demographic characteristics about all 17 interviewees.

The interviews followed a semi-structured interview guide. We started with general questions about the students' studies, Internet experience and experience with Moodle or any other learning platform. Then we asked them about how they liked or disliked Moodle and other general questions to encourage them to talk about their experiences, possibilities, activities and purposes on Moodle. We also asked them to describe their everyday experience on Moodle. To help them remember their specific experiences on Moodle, we asked them to compare their experience on Moodle across various courses. Moreover, we asked them to compare their experience on Moodle with their experience on other learning platforms such as FirstClass. At the time of this study, the school was transitioning from FirstClass to Moodle as its learning management system; while instructors had the choice for a while to use either of the two systems, the school shut down FirstClass by the end of this study, and everyone has had to use Moodle since then. Thus, even for the interviewees who had considerable experience with Moodle, most of them had experience with FirstClass. Thus, many of them were keenly conscious of their experience in transitioning to Moodle, so they could answer from the perspective of discovering new affordances on Moodle. Interview questions about comparing their experiences with the two systems were quite helpful for the interviewees to remember many specific experiences they had.

To analyze the data, we had the recorded interviews transcribed and transferred to Nvivo 10 software for qualitative data analysis. We followed qualitative data analysis guidelines (Charmaz 2006) to openly code the data into every possible action, task, and purpose the interviewees described. In particular, we were cautious about letting our preconceptions from the pilot study affect our coding for the main study; so we used "in vivo" codes to remain close to the data (Charmaz 2006). Initial open coding of the transcribed data by the principal researcher resulted in 33 codes found in 456 quotations. To assure the trustworthiness of our coding, we had a

second coder use our coding schema for coding a random sample of 10% of the quotations. A final year doctoral candidate in Business Administration, the second coder was trained using a pilot test of 17 random quotations (one from each interview). On the basis of the differences found in the pilot test, the original 33 codes were extended to 41, and over 100 quotations were recoded accordingly. We chose 51 random quotations (3 from each interview, different from the training sample) for the second coder. The coder was told the number of codes for each quotation, so we could calculate the kappa. The process resulted in a kappa of 0.89, which is indicative of very high agreement between coders. The two coders discussed and reconciled the differences of the coding of quotations, and this resulted in changes in the coding of 1 of the sampled quotations; moreover, 3 non-sampled quotations were recoded accordingly.

Next, we used axial coding to relate the open codes to each other and to group the related actions and behaviours into functional categories, thus allowing meaningful affordances to emerge. Special caution was given to the fact that affordances a) are functional and thus express students' explained purposes and goals and b) cover the range of behaviours we captured in the interview data. After going through the qualitative coding and analysis process, five main Moodle affordances emerged. Appendix 3-3 displays the results of the open and axial coding processes. Of the seven axial codes we came up with as affordances of Moodle, we decided not to include "Receiving Notification" and "Personalization" for further analysis. Personalization refers to the users' ability to modify their Moodle personal profile, such as changing their photo and personal description that are visible to other users. It includes a single code of "editing personal profile" which occurred in only 1 quotation. While Personalization could be an important affordance of Moodle, it clearly is not well perceived and actualized by the Moodle users in our study. Although Receiving Notification appears relatively frequently (in 23 quotations), it represents a unique type of affordance that we may refer to as an "automatic affordance" designed into the system, as it does not need any user action to be actualized (other than a single action of initially requesting notifications to be sent). While we note and highlight these types of affordances of new technology, we leave them out of the scope of our study, which intends to examine users' intentional and purposive behaviour and actualization of affordances.

Our identification of the affordances took into consideration students' purposes and motives while using Moodle. Appendix 3-4 lists the affordances with some examples of supporting

quotations from students. After analyzing all the interviews, we revised the definitions of the affordances from those used in the pilot study. The five affordances follow:

- **Content Access:** Action possibilities enabling the students to access any course content that they need; these possibilities give the students read-only access to the course-related material.
- **Submission:** Action possibilities enabling the students to submit their work, answers, or ideas for part of their course grade, for which they might or might not receive subsequent feedback.
- **Communication:** Action possibilities enabling the students to communicate and share their ideas, opinions and questions with the teacher, teaching assistants or fellow classmates; or to acquire awareness of what the teacher, teaching assistants or classmates communicated or shared; both parties have the chance to express themselves and engage in two-way interaction.
- **Practice:** Action possibilities enabling the students to practise what they have already learned about the course material.
- **Feedback:** Action possibilities enabling the students to get feedback on their learning, participation, submitted work or status or progress in the course.

Card Sorting: Relating Affordances to Actions

Card sorting was employed to understand how user actions on Moodle actualize the five major affordances identified in the previous step. This step is common to a distinct but somewhat related study (see Essay 2); what follows is a detailed description of the procedure we followed and the results.

The list of actions was extracted from the log data of the 260 students of three sections of the same course that used Moodle for a full semester. This course required an extensive use of Moodle and thus covered a wide range of possible student actions. 53 different actions were identified from the dataset (see Appendix 3-5).

We conducted two rounds of card sorting with multiple experienced student users (called "judges" in card sorting) in each round. There is no definitive rule for the number of judges to be employed, but it is generally agreed that it should be small and may vary depending on the

context and concepts (Anderson and Gerbing 1991). Following the model of Moore and Benbasat (1991), we choose five as the number of judges for each round. In the first round, five judges were asked to sort any of the 53 identified user actions into one of the five identified affordance categories. One of the researchers met with each judge individually in person and explained the procedure and the meaning of each category and action. Then, the judge went through actions on a specially-designed spreadsheet and, considering their personal experiences on Moodle, assigned each action to the most relevant affordance category actualized and fulfilled by that action. For instance, the action defined as "visiting the page to upload files for your assignment" was sorted by everyone into the Submission affordance category, and the action defined as "replying to an existing discussion on a forum" was sorted by everyone into the Communication affordance. At the end, the researcher asked questions about the reasoning behind the judges' choices. This helped us understand users' intentions and the purposes behind their actions and to clarify the definitions of the affordances we provided.

The first round of card sorting practice resulted in inter-rater reliability, Fleiss' kappa of 0.74, demonstrating an acceptable level of agreement between the judges (see Table 3-3); a kappa higher than 0.65 can be considered an acceptable level of inter-rater agreement (Jarvenpaa 1989; Moore and Benbasat 1991). The first round of card sorting resulted in three changes to the definitions of the actions and affordances, clarifying that the first page of quizzes we referred to in our dataset were quiz instructions. Additionally, one of the judges raised the fact that the page for all quizzes includes quiz grades if available, so we highlighted that in its definition. The pilot study had already highlighted the fact that visiting the main page of an assignment could actualize different affordances if it occurred before or after the assignment was submitted, so we incorporated this as well.

For the second round, the procedure of the first round was repeated with ten different experienced student users and the revised set of action definitions. Although Moore and Benbasat (1991) considered five judges sufficient, we used twice that number to increase the rigour of our analysis. Six of the actions received an agreement level of less than 80% in both rounds, so we removed them from the list of actions. The process resulted in inter-rater reliability, a kappa of 0.90, demonstrating very high agreement. Because an agreed-upon list of affordances and actions was attained (see Table 3-3), no more rounds of card sorting were

needed. Appendices 3-5, 3-6 and 3-7 present the content and results of both rounds of the card sorting procedure and the list of actions actualizing each affordance.

Table 3-3. Inter-rater reliability statistics for two rounds of card sorting

Card Sorting Round	Actions (N)	Judges (N)	Kappa scores for inter-rater reliability of affordances							
			Content Access	Submission	Communication	Practice	Feedback	Overall	5% Confidence Interval	
									Lower	Upper
1	53	5	0.77	0.74	0.64	0.80	0.72	0.74	0.69	0.78
2	47	10	0.90	0.94	0.92	0.85	0.86	0.90	0.88	0.92

Cluster Analysis: Identifying Personas

We collected Moodle log data for 456 students in four sections of an introductory business course taught by a single instructor during the same semester. We deliberately chose this specific course for several reasons. First, it uses Moodle extensively: it posts course content, runs weekly quizzes, uses forums, posts assignments and receives submissions, and reports grades on Moodle. Second, our choice controls for the instructor- and course-related variables that could affect students' use of Moodle, like the teaching style and the way Moodle is used for instruction. The students in all four sections used exactly the same integrated Moodle site, as if they belonged to just one section.

The data for the four sections was collected from the Fall 2015 semester. We included only students who did not drop the course, that is, who used Moodle for the whole semester. In all, the dataset recorded over 346,000 actions in Moodle for the 456 students who completed the course.

As a complementary analysis, we also collected and fully analyzed Moodle log data for nineteen sections of two other coordinated courses taught by eight instructors. In fact, even though those courses featured some variations in how Moodle was used, the results were very similar to those for our primary homogenous dataset. Thus, we report only the analysis of our primary dataset in this essay, but the detailed results of the analysis on the larger dataset of 2,393 students are reported in Appendix 3-10.

To prepare the data for processing, we ran hierarchical clustering on the dataset to look for singleton clusters (that is, clusters with only one user); we found no outliers. In order to retain

the variation and the proportional importance of different variables, we chose not to standardize the data. Furthermore, the Pearson correlation measure of distance that we used, as explained later, makes it unnecessary to standardize the dataset.

To conduct the data analysis, R version 3.2.1 was used, including its base package (R. Core Team 2015), cluster package (Maechler et al. 2015), ggplot2 package (Wickham and Chang 2015), reshape2 package (Wickham 2007) and hyperSpec package (Beleites and Sergo 2015). We followed the guidelines provided by Borcard et al. (2011) to conduct agglomerative hierarchical cluster analysis and identify groups of users with similar types of behaviour. This technique is popular because it visually provides the distance between the groups and their sub-groups in a dendrogram diagram (see **Error! Reference source not found.**), so it helps in making an informed decision about the appropriate number of clusters to select. The algorithm starts with one cluster for each data point and then computes the closest clusters and merges them into one cluster. This process of agglomeration continues until it gets to one general cluster including all data points. We employed a clustering method based on between-group linkages in which the average distance between each two members of every two clusters are computed, and the two groups with the smallest average distance are merged. Furthermore, we chose a distance measure of Pearson correlation because our goal is to create personas representing major user behaviours. What matters to us is the *pattern* rather than the *level* of affordance actualization, because we are interested in how users actualize affordances proportionally and in relation to other affordances. Personas would be more informative to a system design team when they are representative of how users use the system rather than how much they use it; this means focusing on the quality of use rather than on its quantity. Hierarchical clustering based on Pearson correlation distance results in clusters of students with highly correlated affordance actualization measures. In other words, students of each cluster supposedly will follow a similar, correlated manner in how they actualize various affordances.

Affordance-based Moodle User Personas

Error! Reference source not found. is the dendrogram depicting the hierarchical clustering results. We chose to cut the dendrogram tree at the height of 0.1 because that gives us three major clusters that demonstrate a significant amount of between-group distance, while the distance among members within a cluster is small. Furthermore, each cluster includes a

meaningful number of members. No outlier or small cluster is detected and all users are clustered into one of the three clusters. Table 3-4 represents the number of users in each cluster and the average number of affordance actualizations for each cluster. It also reports the results of ANOVA for mean differences in affordance actualizations among the three personas.

Figure 3-2 and Figure 3-3 represent the average number of actual and standardized affordance actualizations in each of the three clusters. While

Figure 3-2 keeps the original scale to highlight the differences in the frequency of actualizations between the five affordances, Figure 3-3 standardizes the scale to focus on the differences between the three personas for each affordance.

Table 3-4. The cluster population, mean affordance actualization, and ANOVA results

Cluster	Population Size	Mean Number of Actions Taken to Actualize Each Affordance				
		Content Access	Submission	Communication	Practice	Feedback
Just Do it (P1)	153 (34%)	181.4	173.6	9.1	33.4	32.2
Practice Makes Perfect (P2)	216 (47%)	258.3	180.8	12.7	383.5	52.6
Content is King (P3)	87 (19%)	287.2	126.9	17.3	98.2	46.4
All	**456 (100%)**	**238.0**	**168.1**	**12.4**	**211.6**	**44.6**
F (and p-value) for ANOVA mean differences		47.04 (.000***)	30.03 (.000***)	12.80 (.000***)	328.53 (.000***)	29.99 (.000***)

* means p-value < 0.100; ** means < 0.050; *** means < 0.010

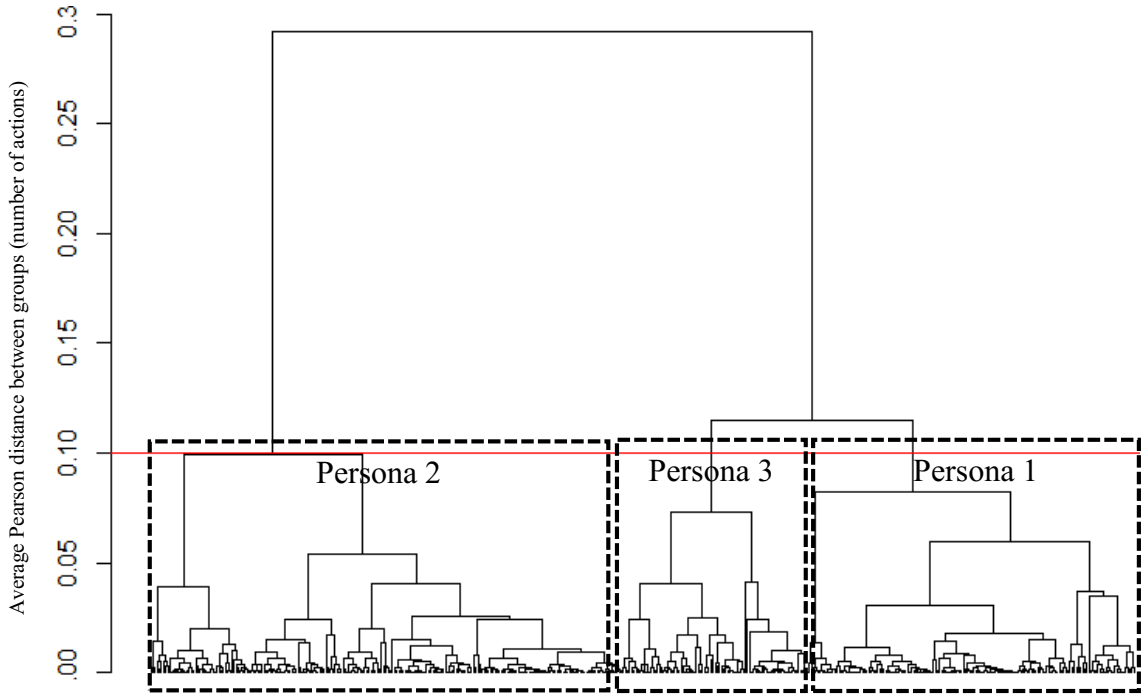

Figure 3-1. Dendrogram resulting from Hierarchical Cluster Analysis

Table 3-5. Tukey HSD test results for mean comparisons of affordance actualizations

Affordance Actualization	Cluster (I)	Cluster (J)	Mean Difference (I-J)	Std. Error	P-value
Content Access	JDI	PMP	-76.84641	9.67886	.000***
		CIK	-105.81001	12.29939	.000***
	PMP	CIK	-28.96360	11.63103	.035***
Submission	JDI	PMP	-7.22467	5.90015	.439
		CIK	46.69822	7.49761	.000***
	PMP	CIK	53.92289	7.09018	.000***
Communication	JDI	PMP	-3.60185	1.27955	.014**
		CIK	-8.17625	1.62599	.000***
	PMP	CIK	-4.57439	1.53763	.009***
Practice	JDI	PMP	-350.04194	14.48996	.000***
		CIK	-64.80663	18.41310	.001***
	PMP	CIK	285.23531	17.41251	.000***
Feedback	JDI	PMP	-20.36574	2.64273	.000***
		CIK	-14.21456	3.35825	.000***
	PMP	CIK	6.15118	3.17576	.130

Sample size: 456. * means p-value < 0.100; ** means < 0.050; *** means < 0.010
JDI: Just Do It user species; PMP: Practice Makes Perfect; CIK: Content is King

Persona 1, characterized as “Just Do It”, comprises 34% of the sample. Users in this cluster mostly actualize affordances of Moodle at the minimum levels; they just do what is required to fulfill their course duties. They actualize all affordances except for Submission at significantly lower levels than other clusters.

Persona 2, characterized as “Practice Makes Perfect”, comprises 47% of the sample. Their use of Moodle is highly focused on actualizing the Practice affordance and somewhat oriented towards the Feedback affordance. Although they actualize the Content Access affordance at a high level, they are not the persona that actualizes Content Access the most.

Persona 3, characterized as “Content is King”, comprises 19% of the users in the sample. The use of Moodle in this cluster is more highly focused on actualizing the Content Access affordance than in the other clusters. Although the users meaningfully actualize the Practice and Feedback affordances of Moodle, these seem to be secondary to their Moodle usage.

The ANOVA results reject the hypotheses for mean equality among the three personas for each of the five affordances (see Table 3-4). That is, for each respective affordance, some of the personas actualize the affordance at significantly different levels. The Tukey HSD test results (see Table 3-5) demonstrate that the three personas are meaningfully differentiated on the five affordances, except in only two cases: Just Do It and Practice Makes Perfect personas are not differentiated in their Submission affordance actualization; and Practice Makes Perfect and Content is King personas are not differentiated by their Feedback affordance actualization.

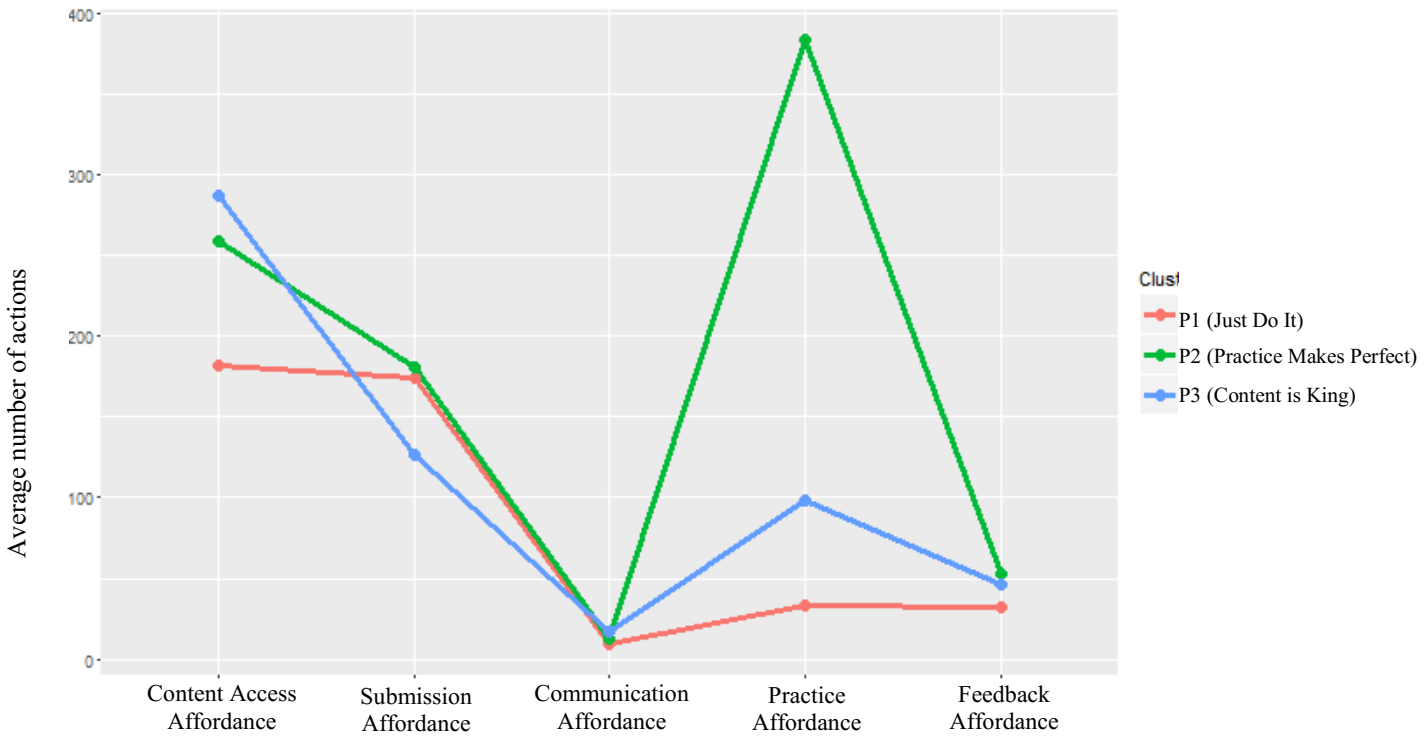

Figure 3-2. Average number of affordance actualizations across personas

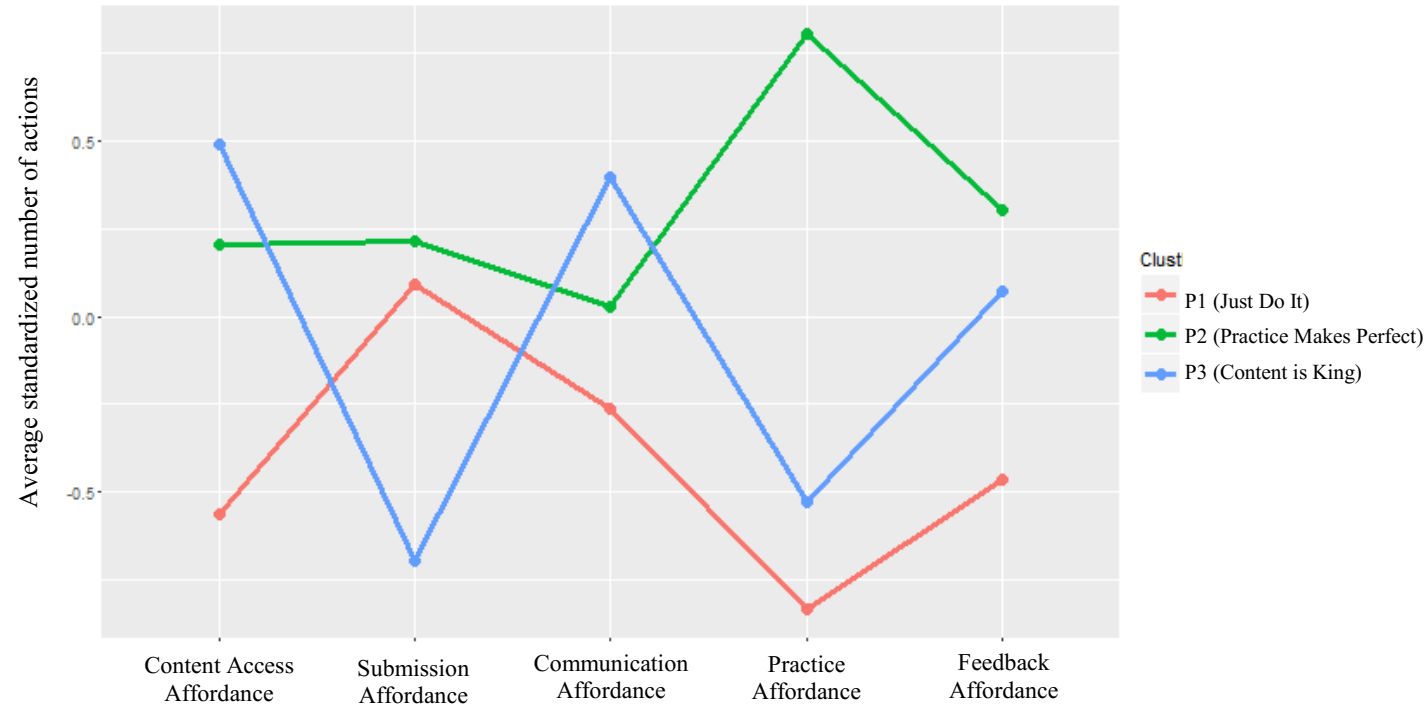

Figure 3-3. Average standardized number of affordance actualizations across personas

To provide further understanding about the three personas and their adaptations to various affordances of Moodle, in Figure 3-4 we use Kernel Density Estimation to analyze the distribution of the three clusters over each affordance (Fieberg 2007). It estimates each persona's density function, which represents the "relative likelihood" for that persona to actualize the given affordance at any specific value. The x-axis displays the level (i.e. the number of actions) at which the given persona actualizes the affordance, and the y-axis displays the relative likelihood for the persona to actualize the affordance at a given level on a scale from 0 to 1. In other words, the diagram represents the estimated distribution of the personas along the range of affordance actualizations.

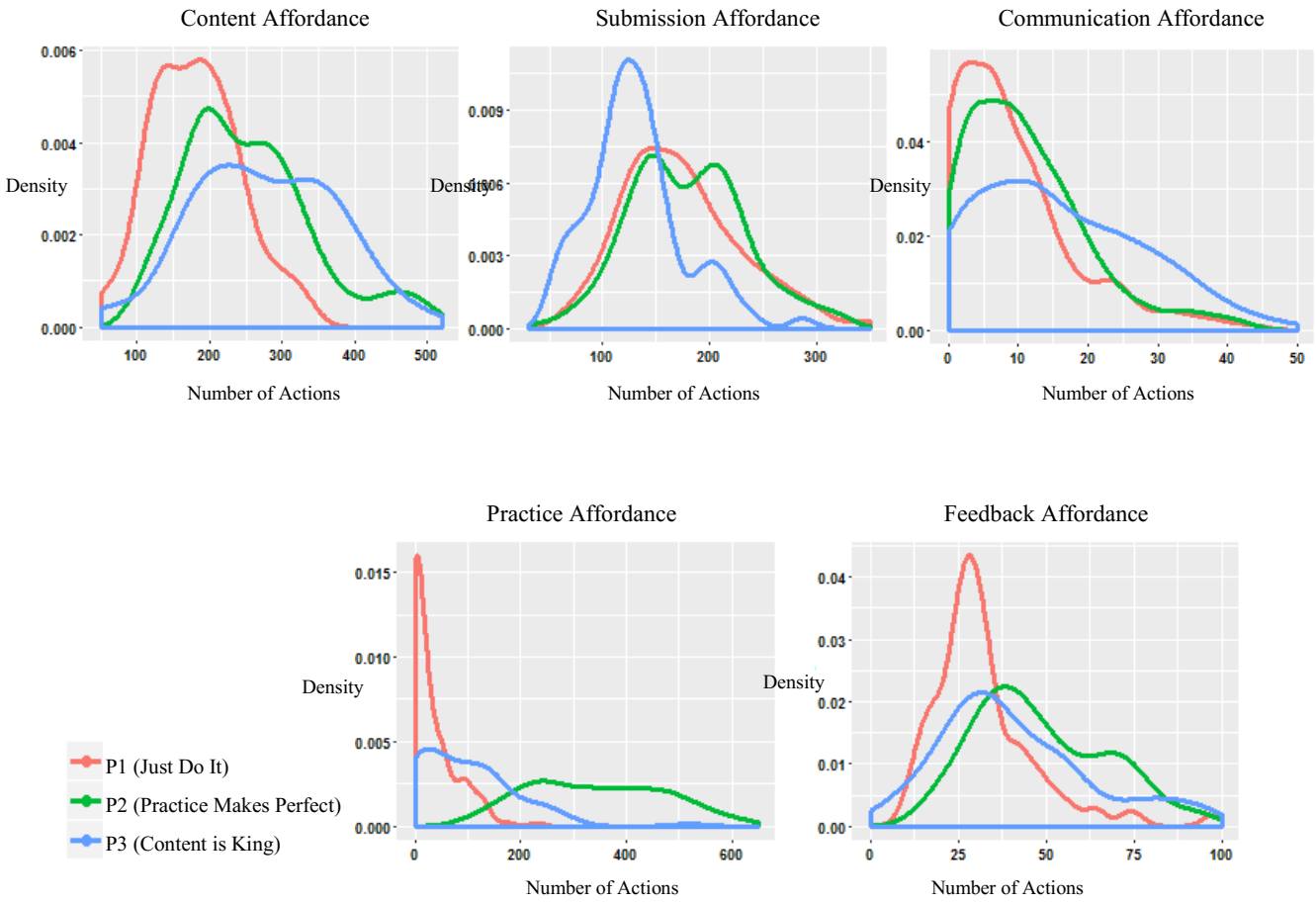

Figure 3-4. Personas distribution over actualization of each affordance using Kernel Density Estimation

For instance, the Practice affordance is the one that differentiates the three personas the best (see Figure 3-4). This means that while the Just Do It persona tends to actualize the Practice

affordance around 50 times and less during the semester, the Practice Makes Perfect persona tends to actualize the affordance in a range of 200 to 600 actions during the semester. In addition, the Submission affordance does not really differentiate the Just Do It and Practice Makes Perfect personas. Similarly, the Feedback affordance is unable to differentiate the Practice Makes Perfect and Content is King personas; that is, the two personas are somewhat similar in their actualization of the Feedback affordance. Next, we turn to creating qualitative-only personas and presenting independently-developed qualitative-only personas so that we can compare such personas with the affordance-based ones we developed here.

COMPARATIVE DEVELOPMENT OF PERSONAS USING EXISTING APPROACHES

One of the primary contentions of this study is that the affordance-based personas that we describe benefit from the advantages of those developed using existing quantitative- and qualitative-only methods and offer further numerous benefits. To illustrate the value of affordance-based personas compared to either quantitative or qualitative personas, we used our collected data to create and analyze alternative personas using best practices from the classical approaches. We used the Moodle log data to create quantitative personas using Principal Component Analysis (PCA), which is arguably the most credible quantitative persona creation technique (Brickey et al. 2012). Moreover, we draw on previously designed Moodle user personas created using three case studies (Operandi 2014) to compare personas developed by only qualitative methods. In the following, we report our empirical data collection and analysis, the affordance-based personas, the quantitative personas, and the pre-built qualitative personas. In the discussion section of this essay, we will compare these three types of personas and assess the insights obtained from our proposed affordance-based mixed-methods approach.

Quantitative Moodle User Personas

Among the various quantitative techniques for creating user personas, Principal Component Analysis (PCA) has been demonstrated to be the most credible technique (Brickey et al. 2012). PCA is a dimension reduction technique that finds the few components that can account for most of the variance in observations of many variables. We followed the steps provided by Sinha (2003) and Brickey et al. (2012) to use PCA to analyze the Moodle log data of the 456 users of our sample.

Appendix 3-8 reports the results of PCA with varimax rotation using SPSS 20. The eigenvalue scree plot suggests three as the minimum number of components that accounts for a meaningful amount of variation among the 31 user actions in the dataset. (The quantitative-only persona analysis has only 31 actions represented in the raw log data versus 47 for our proposed methodology because it does not benefit from the qualitative insights that enabled us to fine-tune the differences between many log data actions.) The three components account for 20%, 13%, and 9% of the variance, respectively. Examining the rotated component matrix and the actions that significantly load on each component with loading of over 0.7, we came up with the following three quantitative personas.

1. PC1, characterized as "Quizzer", heavily uses quiz-related features by starting, doing and submitting quizzes, reviewing quiz responses, and checking the summary of their quiz attempts.
2. PC2, characterized as "Time Manager", uses calendar and scheduler features by creating and updating calendar events, and adding, checking, or removing booking schedules. They use the Moodle calendar to remind themselves of specific deadlines and events. Also, they use the scheduler to make appointments with the instructor or TA for meetings.
3. PC3, characterized as "Forumer", frequently checks the main pages of forums and the discussion pages for various forums. They also have a tendency to check the list of users and their profile pages. Moreover, they tend to check their grades.

Next, we draw on three pre-built qualitative personas and examine how they are supported in our dataset.

Qualitative Moodle User Personas

Due to the contextual richness of the resulting personas, qualitative techniques are the most popular ones for creating user personas (Brickey et al. 2012). However, it is beyond the scope of this study to go through the lengthy process of creating completely alternate personas based solely on qualitative data. To be able to compare and contrast affordance-based personas with their qualitative counterparts, here we draw on existing research that has developed such personas for Moodle users. Specifically, we refer to the three Moodle user personas built through three qualitative case studies by Operandi (2014). The three personas are as follows:

1. “Miss Dependent” is very much dependent on the teacher for what she needs to learn; she is focused on the facts introduced to her in the course, rather than on their applications and implications. She is comfortable with procedural learning and practises answering short-answer questions. She values the instructor’s feedback on her progress and does not like the stress of quizzes. She is representative of 3 students interviewed by Operandi (2014).
2. “Mr. Cue-Conscious” needs to know the criteria on which he is going to be assessed in the course. He cares more about his grade than about his learning. He is not interested in exchanging feedback with other students. He does not discuss assessments with peers but feels OK to criticize peers’ work anonymously if he can. He is representative of 5 students interviewed.
3. “Mr. Personal Journey” values his personal interests and takes responsibility for following and learning them. He values his peers and their ideas and thinks their exchanges can be beneficial to both. To him, learning is not only about extending his knowledge, but also about changing his personality, habits and learning capacity. He is representative of 4 students interviewed.

To demonstrate the credibility of the three aforementioned personas in the context of our sample of Moodle users, we analyzed the data from the 17 interviews that we conducted to verify if Operandi’s three personas could represent the students in our sample. We extracted relevant quotations that could support characterizing our interviewed students according to Operandi’s personas, and we indeed confirmed that his classification based solely on qualitative data could reasonably characterize the students we interviewed (see Appendix 3-9). Thus, we can legitimately use Operandi’s personas as a representation of what could be produced by a purely qualitative persona development methodology applied to our particular data. In the following section, in addition to discussing our results in general, we specifically compare the advantages and disadvantages of the three types of personas.

DISCUSSION OF THE PERSONAS

In this study, we discuss various methods for creating user personas and suggest a new mixed-methods approach for creating personas based on users’ actualization of technology affordances. To illustrate the applicability and value of this new approach, we first collected and analyzed

data to create Moodle user personas using the affordance-based approach that we present. Then, to illustrate the relative value of this new approach, we also used best practices to create personas based on only quantitative analysis of our dataset, and we also analyzed our interview data from the perspective of three independently-developed Moodle user personas using only qualitative analysis. Table 3-6 summarizes the three types of Moodle personas. Comparing these three approaches to developing personas (our new affordance-based approach, a quantitative-only approach and a qualitative-only approach) provides multiple insights on the advantages of affordance-based personas that address the shortcomings of the other approaches depicted in Table 3-2.

Table 3-6. Three types of Moodle personas

Affordance-Based	Quantitative-Only	Qualitative-Only
• **Just Do It:** actualizes affordances at minimal levels to just do what is required for course • **Practice Makes Perfect:** primarily focused on Practice and somewhat on Feedback; actualizes Content at high levels but not the most • **Content is King:** primarily focused on Content; actualizes Practice and Feedback at somewhat high levels, but not as the main focus	• **Quizzer:** heavily uses quiz-related features • **Time Manager:** uses calendar and scheduler features • **Forumer:** frequently checks forum pages, grades, as well as profile pages of others	• **Miss Dependent:** highly dependent on teacher; prefers procedural learning and close feedback • **Mr. Cue-Conscious:** cares more about grade than about learning, so very focused on cues about what they need to do • **Mr. Personal Journey:** takes responsibility for creating their own learning experience; interacts with and learns from others

First, our affordance-based personas are grounded in and representative of the data from a large sample of users. This is the primary advantage of quantitative-only personas over qualitative-only ones. The grounding in a large body of users makes it easy to communicate such personas to system development teams because they can be supported by objective user data. For instance, the affordance-based Just Do It, Practice Makes Perfect and Content is King personas represent respectively 34%, 47% and 19% of 456 sample users (100%). Similarly, quantitative-only Quizzer, Time Manager and Forumer personas capture all 456 users of our sample. In contrast, the qualitative-only Miss Dependent, Mr. Cue-Conscious, and Mr. Personal Journey are created on a base of only 3, 5 and 4 students, respectively, whom the researcher interviewed; it is not

clear if they can are representative of a larger Moodle user community. In addition, the relative size of the personas provided by the affordance-based approach can be indicative of the relative importance of those personas to system design teams. For instance, the 47% size of the Practice Makes Perfect persona may prioritize it over the 19% size of the Content is King persona when it comes to making design decisions.

Second, similar to quantitative-only personas, our affordance-based personas are created using a method that is not overly dependent on the experience and cognitive capabilities of the personas' designer. For instance, the qualitative personas are built completely on the basis of user interviews that require particular qualitative analysis skills to conduct and interpret them. In contrast, our affordance-based personas are built using interview, card sorting, and log data analysis in which the persona designers' qualitative analysis skills play a considerably smaller role. On the one hand, qualitative skills are indeed needed for identifying affordances from interview data, which is more demanding than with quantitative-only personas. On the other hand, this cognitive task is much simpler than that required to create complete personas from the data, as in the case of qualitative-only personas. In all, the proposed method requires fewer cognitive capabilities and less experience from the persona designers.

Third, our affordance-based personas provide the context about the personas over and above merely describing the actions that the users take. These personas entail the meaning and purpose of the actions taken and provide an understanding of the objectives that the actions serve. For instance, whereas the quantitative personas of Forumer and Time Manager refer mostly to the number of related and unrelated actions that comprise the respective personas, they do not involve the users' purposes and reasons for taking those actions. They do not even explain how those actions relate to each other. Thus, it is the responsibility of the persona designers to try to interpret and explain the relations among the actions. For example, it is not clear how and why Forumers would check their grades and what the purpose of such behaviour would be. However, the affordance-based method takes care of this issue by using card sorting to find the relation between actions and the affordances they actualize. If the assignment of actions to affordances is not clear, then the user judges can explain to the persona designers the logic and provide the context for their actions. We note that although qualitative-only personas are much more likely

than quantitative-only ones to incorporate the purposes of actions, they do not link those purposes to user actions as explicitly as the affordance-based approach we describe.

Fourth, the affordance-based personas are less about who the users are and more about how and why they use and interact with the system and for what purpose they do so. This results in personas that are more readily usable and insightful in making the design decisions. For instance, it would not be easy to make insightful design decisions that support Miss Dependent, Mr. Cue-Conscious and Mr. Personal Journey in their Moodle use because we do not understand very well how their focus on facts, grades or personal learning, respectively, affects their use of Moodle. However, affordance-based personas provide readily usable insights for system design teams. For instance, the Just Do It persona may need all the affordances in a single place rather than fully featured affordances put in different places; a dashboard with all updates and relevant links to the active quizzes and assignments might serve the Just Do It persona well.

Fifth, the affordance-based personas provide the behavioural patterns of the personas rather than merely presenting a number of behavioural or demographic variables. This provides further insight for design decisions. For instance, the Quizzer quantitative-based persona identifies a list of the quiz-related actions that should be supported by the designers, but this does not provide much guidance as to what exactly this persona needs. However, the development of the Practice Makes Perfect affordance-based persona reveals heavy dependence on quiz-related actions as well as on feedback-related ones. So the designers could readily understand that they need to incorporate more feedback in practice-related features. Whereas the quantitative-based personas highlight specific actions, the affordance-based personas place those actions in context and interrelation to each other, which can readily guide sensible design decisions.

Sixth, the affordance-based personas address the limitations of the current mixed-methods approaches (see Table 3-2). The existing mixed-methods approaches use quantitative-only methods to group users into clusters or personas, and then they use qualitative data from those users to provide context and enrich the personas. Consequently, they do not use the qualitative insights in identifying the personas, but only in enriching them after they have been identified. However, the affordance-based personas we describe are identified by analyzing quantitative data at the level of qualitative affordances. For instance, the Just Do It persona is identified by its minimal actualization of four out of five qualitative affordances. Such a powerful mingling of

quantitative and qualitative insights leverages the full potential of the mixed-methods approach and provides rich and representative personas.

While this study demonstrates the applicability and advantages of affordance-based persona creation, there is a valid question about the generalizability of the results: how generalizable and usable are the personas if they are built on homogenous sample users of a certain implementation of a system, like Moodle in this case? Although affordance-based and quantitative personas prove to be more generalizable than qualitative ones, they have not been able to address the generalizability concern in full. While we do not expect universal personas of customizable systems like Moodle to exist independently of the specific system configuration in use, persona designers need to be specific about the boundaries of generalizability of the created personas. For that purpose, we repeated our persona creation with the same interview and card sorting data, but using a larger and more diverse Moodle log dataset comprising a total of 2,393 students from 23 sections of three courses in the same business school, including the course of 4 sections with 456 students that we analyzed here. Appendix 3-10 reports the dataset and the analysis that resulted in the same three personas we have developed in this study. Comparing the results, it is safe to say that the same three affordance-based personas are representative of Moodle users in the larger, more heterogeneous dataset as long as the specific system configuration provides the same basic features, for example, content (text and files), practice (quizzes) and feedback (grades).

However, with the larger dataset, considering the patterns and the size of Moodle use, three of the five affordances available to Moodle users appear to be more important in shaping user experience and personas: Content Access, Practice, and Feedback. These were actualized at very high levels and successfully differentiate the three personas, except for Feedback which only marginally differentiates the Content is King and Practice Makes Perfect personas; this may be indicative of less different use of Feedback by those two personas compared to its distinctly lower use by Just Do It users. The Submission affordance, although partially differentiating the three personas, was mandated by the instructors for part of the course grade. Therefore, its actualization was mostly regulated by the instructors, and it would not be reflective of student preferences. Although the Communication affordance differentiates the three personas, it was actualized at very low levels in general, with an average of 12.8 actions throughout the semester.

This finding is consistent with the qualitative evidence from students that they would rather use Facebook and other social media for course-related communications with each other than use Moodle.

CONCLUSION

This study reviews the current approaches to persona creation in user-centred design of technology and highlights the advantages and disadvantages of each (see Table 3-2). While the more popular qualitative approaches provide contextually rich personas, they are built on few users and are not very representative of the general user community. In contrast, quantitative personas are built on demographic or log data from a larger user sample, but they lack the contextual richness needed to understand what the personas represent. Existing mixed-methods approaches create user personas quantitatively based on large samples of users and then enrich the personas with further contextual information acquired qualitatively. However, in doing so, they do not use the qualitative insights during the phase of identifying the personas but only retrospectively to enrich the identified personas.

To address the limitations of the current approaches to persona creation, this essay proposes a mixed-methods approach to group users according to their patterns of affordance actualizations. Affordances are the action possibilities provided by a system that guide user behaviour; they entail the purpose or objectives the actions serve, and therefore they put user actions in the richer context of users' purposes. The proposed approach qualitatively identifies the technology affordances, then uses card sorting to identify the user actions that actualize those affordances. Then, it analyzes large sets of user log data at the levels of the affordances they actualize rather than at the level of actions, as is done with the existing quantitative approaches. It clusters users to produce the personas that actualize affordances with distinct patterns.

To illustrate the applicability and value of the proposed method, we empirically created Moodle user personas in the context of a North American business school. The collection and analysis of the interview and card sorting data is in common with the second essay of this thesis. However, the log data collected and analyzed for this study is distinct, though the log data analyzed in the second essay is a subset of the log data analyzed in Appendix 3-10 of this essay. The affordance-based approach resulted in three Moodle user personas: Just Do It, Practice Makes Perfect, and

Content is King. We used PCA to analyze the same user log data and build quantitative-only personas. We also drew on independently developed qualitative-only Moodle user personas (Operandi 2014) to be able to compare and contrast the advantages of our affordance-based method.

The affordance-based personas have some significant advantages over those of the existing approaches. First, they are grounded in and representative of the data from a large sample of users, unlike qualitative-only personas. Second, their development does not require the intense qualitative skills of qualitative-only personas. Third, they provide the context about the personas over and above the actions they take, unlike quantitative-only personas. Fourth, they are less about who the users are and more about how and why they use and interact with the system and for what purpose they do so. This results in personas that are more readily usable and insightful in making design decisions. Fifth, they provide the behavioural patterns of the personas rather than presenting merely a number of behavioural or demographic variables associated with them. This provides further insight for making design decisions that support the personas. Sixth, they address the limitations of the current mixed-methods approaches by identifying personas that make optimal use of both quantitative and qualitative data rather than simply identifying personas quantitatively and then enriching them qualitatively, as is done by the current methods.

The proposed affordance-based approach to user persona creation has important implications for research and practice. For persona research, it highlights the need and feasibility of new approaches that provide contextually rich and more representative personas. This affordance-based approach is a viable alternative that can cover most of the limitations of the existing approaches. It suggests affordance actualization as a new and fruitful unit of analysis for user behaviour research. Affordances entail the meaning and purpose of user actions, so they provide the context in which the actions should be understood. For IS research, the suggested technique provides new analytical tools to quantify affordance actualizations and analyze user behaviour in terms of the patterns of user actualization of affordances rather than merely in terms of the actions they take. Over and beyond these implications, this study highlights the potential of the affordance theory for bridging the design-oriented persona research and the behavioural IS research. It demonstrates how design research can benefit from more behavioural approaches to examine and analyze patterns in user behaviour.

For persona designers in general, this study provides detailed tools and techniques to create personas using a combination of qualitative data collection and quantitative user log data. It is practical because it can be conducted with just a few interviews, a few rounds of card sorting, and readily available user log data. It provides persona designers with practical insights on user behaviour patterns and on how to improve the system to support those patterns.

For designers and instructors of the Moodle community specifically, this study highlights three major personas with distinct patterns of Moodle use in a context of rich use of Moodle features. Just Do It users may be supported by having a dashboard that provides them with the access to updates, assignments, forums and quizzes that they need to attend to at any given time. They appreciate receiving announcements or notifications about updates and changes on the site. At the same time, they would be bothered if they received too many notifications, for instance for forum posts, that they do not care about.

Practice Makes Perfect users appreciate any opportunity to practise their knowledge and also like to know how they are performing on those practice exercises and in the course in general. They could be supported by incorporating rich feedback into the quiz features and other submission capabilities. It also would be good for instructors and Moodle system administrators to offer a larger variety of question types in the quiz feature; students would appreciate being able to draw diagrams or manipulate data to answer a question, and so supporting more interactive types of questions would be valuable. (In the instance we studied, the quizzes were mainly textual multiple-choice questions with little variation.) Instructors could support this persona by providing further quizzes and make sure that students are given the correct answers after each question or after the quiz is finished; more explanation on the correct option would be appreciated by the students.

Content is King users are primarily concerned with accessing and using content and material related to the course. They can be supported by giving them easy access to a variety of content types. They like being able to open a file (i.e. Word, PDF, or PowerPoint) in their browser without downloading it. They also like having access to a greater variety of content, such as playing a video directly from Moodle rather on a second page. In addition, they want notifications whenever new content is added.

There are some limitations of this study to note. First, although the affordance-based personas are not only built on qualitative data analysis, they nonetheless depend on qualitatively-derived technology affordances; so the persona designers will still need some experience and cognitive capacity in analyzing qualitative data. Since the user log data will be analyzed on the basis of the affordances identified, it is essential to identify the major and significant affordances of the technology. However, the card sorting exercise greatly helps to properly modify and improve the identified affordances. For instance, if any major affordance is missing, then some frequent actions might not be properly sorted into the available affordances. Second, the required types of data for this methodology may limit its applicability in certain contexts. For example, it might be difficult to apply this methodology for creating personas for new technologies that have not existed or been implemented before, as well as for technologies that do not record usage log data. Third, the generalizability of the personas created should always be considered with respect to the specific implementation of the system studied. As is the case with all persona design, there is no such thing as a universally applicable persona independent of the specific system implementation and organizational context.

Future research could extend this study in a number of ways. For one, in our analysis of the interview data to identify the affordances, we found quotations attesting to a distinct type of affordances, characterized as "automatic affordances" that do not necessarily depend on user actions for their actualization but are rather initiated by the system. The main instance was when users receive email notifications or announcements from the teacher or about postings in the forums. Although such affordances might not be considered for the creation of personas, they could be consequential and necessary for supporting some of the personas. Another potential direction for research concerns the question of the generalizability of personas in general and affordance-based personas in particular. In the case of customizable systems, it is especially important to understand how personas would be different for various salient configurations of the system, and how the designers can reflect those differences in their design. Lastly, while we conceptually compared and contrasted the three types of personas, it would be insightful if further research could empirically compare the applicability and consequences of the three types of personas and their influence on the system's design.

Thesis Conclusion

The IS literature only marginally addresses *the role of the technological artifact in shaping user sensemaking and adaptation behaviour*. Consequently, it is unable to adequately inform technology design on how to improve user sensemaking and the adaptation of technology into organizational routines. This lack highlights the need for new conceptual and analytical tools to be able to account for the role of the IT artifact in explanations of technological phenomena (Benbasat and Zmud 2003; Orlikowski 2010).

This thesis consists of essays that propose an ecological approach to examine the role of the technology artifact in various aspects of user-technology interaction. Ecology has a century-long history of analyzing how organisms evolve and adapt to their environment. We draw on ecology theory and ecological psychology to adapt and employ the concepts of species and niche, along with the theory of affordances, to examine user interaction and adaptation to the technological artifact. The thesis suggests that users' perceptions of technology affordances are related to the technological artifact to which they adapt as well as to some characteristics of the users. Moreover, it draws on concepts of species and niche to analyze the patterns of user adaptation to technology. It provides a new mixed qualitative-quantitative methodology to identify species with various affordance actualization behaviours to represent personas (i.e. fictional characterizations of potential system users) employed in the process of system design and development.

SUMMARY OF THE THREE ESSAYS

The first essay reviewed and synthesized the current research on organization-technology sensemaking. It identified four major streams in organizational sensemaking research that treat sensemaking and sensegiving at individual and collective levels. Figure 1-2 and Figure 1-3 represent the resources and practices on which the individuals and collectives draw for sensemaking and sensegiving. Technology sensemaking research consists of two different streams. One examines sensemaking through technology and the design characteristics of the individual and collective sensemaking support systems (Table 1-5). The other investigates sensemaking about technology and the social and cognitive processes of understanding new

technologies (Table 1-6). While the dominant approach to sensemaking research sheds light on many social and cognitive aspects of the sensemaking phenomenon, it rarely pays attention to the role that the material artifact may play in shaping various understandings of the technology-organization phenomenon. This essay identified three major shortcomings in the extant literature: lacking technology materiality, neglecting the discovery aspect of perception, and lacking action orientation. It laid the groundwork for an alternative approach based on ecological tenets consistent with a critical realist perspective.

To follow the first essay and address the missing role of the IT artifact in user sensemaking of technology, the second essay provided an ecological framework that analyzes user species' sensemaking of technology in relation to their technoniche and personal characteristics. It proposed appropriate methodological tools for ecological analysis of technological ecosystems. Moreover, it empirically illustrated the applicability of the proposed approach and methodology with fruitful insights from analyzing users' sensemaking of the focal implementation of Moodle in a real-life scenario. The empirical study identified five major Moodle affordances: Content Access, Submission, Communication, Practice, and Feedback. Analysis of user log data identified three species (Minimal, Moderate, and Maximal users) that adapt to distinct technoniches that actualize three of the five affordances: Content Access, Practice, and Feedback. Submission and Communication affordances were excluded from the species' technoniche because of their mandatory use or their infrequent usage by the users, respectively, which resulted in their inability to differentiate the species. While Minimal users perceived Moodle primarily for its Content Access capabilities, the Moderate users came to see Moodle as a place not only to access content but also to practise their knowledge. Consistent with their technoniche, Maximalist users tended to make sense of Moodle as a place to access content, practise their knowledge, and acquire feedback on their progress. Users' visual learning style played a role in Moodle user speciation. Users with the highest visual learning scores tended to adapt to Moodle minimally. Moreover, gender indirectly affected the speciation: male users tended to be more visual than verbal learners, and the visual learners tended to adapt Moodle as Minimalists.

The third essay used the ecological ideas to propose a new technique to create user personas based on patterns of affordance actualization by users. It reviewed the current approaches to

persona creation and highlighted the advantages and disadvantages of each (see Table 3-2). Then it proposed a mixed-methods approach to group users based on their patterns of affordance actualizations. Affordances are the action possibilities provided by a system that guide user behaviour; they entail the purpose or objectives the actions serve, and thus they put user actions in the richer context of users' purposes. To illustrate the applicability and value of the proposed method, we empirically created Moodle user personas in the context of a North American business school. The affordance-based approach resulted in three Moodle user personas: Just Do It, Practice Makes Perfect, and Content is King. We used PCA to analyze the same user log data and build quantitative-only personas. We also drew on independently developed qualitative-only Moodle user personas (Operandi 2014) to be able to compare and contrast the advantages of our affordance-based method.

The affordance-based personas appear to have some significant advantages over the existing approaches. First, they are grounded in and representative of the data from a large sample of users, unlike qualitative-only personas. Second, their development does not require the intense qualitative skills of qualitative-only personas. Third, they provide the context about the personas over and above the actions they take, unlike quantitative-only personas. Fourth, they are less about who the users are and more about how and why they use and interact with the system and for what purpose they do so. This results in personas that are more readily usable and insightful for making design decisions. Fifth, they provide the behavioural patterns of the personas rather than presenting merely a number of behavioural or demographic variables associated with them. This provides further insight for making design decisions that support the personas. Sixth, they address the limitations of the current mixed-methods approaches by identifying personas that make optimal use of both quantitative and qualitative data rather than simply identifying personas quantitatively and then enriching them qualitatively, as is done by the current methods.

CONTRIBUTIONS OF THE THESIS

In all, the three essays contribute to IS research in terms of theory, methodology and practice. Theoretically, this thesis contributes to research by extending the current socio-cognitive approaches to user-technology interaction. It examines the role of the technology artifact in user sensemaking of technology. It proposes the concept technoniche that provides theoretical tools to

examine user adaptation to the IT artifact and its relation to user sensemaking of new technology. Moreover, the concept of user species provides a fruitful new level of analysis for behavioural and adaptation IS research by grouping and studying users according to their adaptive behaviour. In addition, this thesis bridges design-oriented HCI research and behavioural IS research by examining user behavior in relation to the IT artifact. The ecological approach links the two areas and contributes to the common body of knowledge relevant to both.

Methodologically, this thesis contributes to IS research by providing the analytical tools required to empirically examine the relation between the user and the technological artifact. The innovative combination of interviews, card sorting, surveys and cluster analysis to relate user actions to affordances provides a helpful way to quantify affordance actualizations and study users' adaptive behaviour as it unfolds. The analysis of the survey data at the level of user species which is identified by analysis of user log data provides a unique way of analyzing users' sensemaking in relation to their adaptation to technology. The specific combination of the research methods suggested to examine the ecological approach sets an example for the design of research methods that capture the theoretical meaning in IS theorization (Bagozzi 2011).

Practically, this thesis contributes to technology implementation and design practitioners by providing them with the appropriate techniques to analyze users' sensemaking in relation to their adaptation to the IT artifact. System development teams can use the proposed methodology to bring insight on how to support sensemaking of the technology. For instance, our ecological analysis of a Moodle ecosystem explains the distinct adaptation of the users who understand Moodle as a place for content access and practice (Moderate users) in terms of the exact features they use and the level of their dependency on these features. Therefore, such sensemaking of Moodle may be supported by facilitating use of the related features together. Moreover, system designers could help evolve the users to a higher level of adaptation (Maximalists) by enclosing and further integrating the feedback features with the practice ones. For persona designers, this thesis provides detailed tools and techniques to create personas using a combination of qualitative data collection and quantitative user log data. It is practical because it can be conducted with just a few interviews, a few rounds of card sorting, and readily available user log data. It provides persona designers with practical insights on user behaviour patterns and how to improve the system to support those patterns.

References

Abelson, R. P. 1981. "Psychological status of the script concept," *American Psychologist* (36:7), pp. 715–729 (doi: 10.1037/0003-066X.36.7.715).

Adlin, T., Pruitt, J., Goodwin, K., Hynes, C., McGrane, K., Rosenstein, A., and Muller, M. J. 2006. "Putting Personas to Work," in *CHI '06 Extended Abstracts on Human Factors in Computing Systems*CHI EA '06, New York, NY, USA: ACM, pp. 13–16 (doi: 10.1145/1125451.1125456).

Adolph, K. E., Eppler, M. A., and Gibson, E. J. 1993. "Development of perception of affordances," *Advances in Infancy Research* (8), pp. 51–98.

Allinson, C. W., and Hayes, J. 1996. "The Cognitive Style Index: A Measure of Intuition-Analysis For Organizational Research," *Journal of Management Studies* (33:1), pp. 119–135 (doi: 10.1111/j.1467-6486.1996.tb00801.x).

Anderson, C. 2011. "Health Information Systems Affordances: How the Materiality of Information Technology Enables and Constrains the Work Practices of Clinicians," Computer Information Systems Dissertations, Georgia State University (available at http://digitalarchive.gsu.edu/cis_diss/45).

Anderson, J. C., and Gerbing, D. W. 1991. "Predicting the performance of measures in a confirmatory factor analysis with a pretest assessment of their substantive validities," *Journal of Applied Psychology* (76:5), pp. 732–740 (doi: 10.1037/0021-9010.76.5.732).

Attfield, S., and Blandford, A. 2011. "Making Sense of Digital Footprints in Team-Based Legal Investigations: The Acquisition of Focus," *Human–Computer Interaction* (26:1-2), pp. 38–71 (doi: 10.1080/07370024.2011.556548).

Azad, B., and Faraj, S. 2008. "Making e-Government systems workable: Exploring the evolution of frames," *The Journal of Strategic Information Systems* (17:2), pp. 75–98 (doi: 16/j.jsis.2007.12.001).

Bagozzi, R. P. 2011. "Measurement and Meaning in Information Systems and Organizational Research: Methodological and Philosophical Foundations," *MIS Quarterly* (35:2), pp. 261–292.

Baker, J., Jones, D. R., and Burkman, J. 2009. "Using Visual Representations of Data to Enhance Sensemaking in Data Exploration Tasks," *Journal of the Association for Information Systems* (10:7), pp. 533–559.

Bakker, S., Lente, H. van, and Engels, R. 2012. "Competition in a technological niche: the cars of the future," *Technology Analysis & Strategic Management* (24:5), pp. 421–434 (doi: 10.1080/09537325.2012.674666).

Balogun, J., and Johnson, G. 2004. "Organizational Restructuring and Middle Manager Sensemaking," *The Academy of Management Journal* (47:4), pp. 523–549 (doi: 10.2307/20159600).

Bansler, J. P., and Havn, E. 2004. "Technology-Use Mediation: Making Sense of Electronic Communication in an Organizational Context," *Scandinavian Journal of Information Systems* (16), pp. 57–83.

Bansler, J. P., and Havn, E. 2006. "Sensemaking in Technology-Use Mediation: Adapting Groupware Technology in Organizations," *Computer Supported Cooperative Work (CSCW)* (15:1), pp. 55–91 (doi: 10.1007/s10606-005-9012-x).

Barki, H., Titah, R., and Boffo, C. 2007. "Information System Use–Related Activity: An Expanded Behavioral Conceptualization of Individual-Level Information System Use," *Information Systems Research* (18:2), pp. 173–192 (doi: 10.1287/isre.1070.0122).

Barley, S. R., Meyerson, D. E., and Grodal, S. 2010. "E-mail as a Source and Symbol of Stress," *Organization Science* (22:4), pp. 887–906 (doi: 10.1287/orsc.1100.0573).

Barrett, M. I. 1999. "Challenges of EDI adoption for electronic trading in the London Insurance Market," *European Journal of Information Systems* (8:1), pp. 1–15.

Bartunek, J., Krim, R., Necochea, R., and Humphries, M. 1999. "Sensemaking, sensegiving, and leadership in strategic organizational development," in *Advances in qualitative organizational research* (Vol. 2), JAI Press Inc., pp. 37–71 (available at https://www2.bc.edu/~bartunek/representative%20publications_files/Bartunek%20Krim%20Necochea%20Humphries.pdf).

Basu, K., and Palazzo, G. 2008. "Corporate Social Responsibility: A Process Model of Sensemaking," *Academy of Management Review* (33:1), pp. 122–136 (doi: 10.5465/AMR.2008.27745504).

Baum, J. A. C., and Singh, J. V. 1994. "Organizational Niches and the Dynamics of Organizational Mortality," *American Journal of Sociology* (100:2), pp. 346–380 (doi: 10.2307/2782073).

Bean, C. J., and Eisenberg, E. M. 2006. "Employee sensemaking in the transition to nomadic work," *Journal of Organizational Change Management* (19:2), pp. 210–222 (doi: 10.1108/09534810610648915).

Beaudry, A., and Pinsonneault, A. 2005. "Understanding User Responses to Information Technology: A Coping Model of User Adaptation," *MIS Quarterly* (29:3), pp. 493–524.

Beleites, C., and Sergo, V. 2015. *hyperSpec: a package to handle hyperspectral data sets in R* (available at http://hyperspec.r-forge.r-project.org).

Benbasat, I., and Zmud, R. W. 2003. "The identity crisis within the IS discipline: Defining and communicating the discipline's core properties," *MIS Quarterly* (27:2), pp. 183–194.

Berente, N., Hansen, S., Pike, J., and Bateman, P. 2011. "Arguing the Value of Virtual Worlds: Patterns of Discursive Sensemaking of an Innovative Technology," *MIS Quarterly* (35:3), pp. 685–709.

Bernhard, E., Recker, J., and Burton-Jones, A. 2013. "Understanding the Actualization of Affordances: A Study in the Process Modeling Context," *ICIS 2013 Proceedings* (available at http://aisel.aisnet.org/icis2013/proceedings/ResearchInProgress/41).

Betton, J., and Dess, G. G. 1985. "The Application of Population Ecology Models to the Study of Organizations," *The Academy of Management Review* (10:4), pp. 750–757 (doi: 10.2307/258043).

Bird, S. 2007. "Sensemaking and Identity," *Journal of Business Communication* (44:4), pp. 311–339.

Bloomfield, B. P., Latham, Y., and Vurdubakis, T. 2010. "Bodies, Technologies and Action Possibilities When is an Affordance?," *Sociology* (44:3), pp. 415–433 (doi: 10.1177/0038038510362469).

Boland, R. J. 1984. "Sense-Making of Accounting Data As a Technique of Organizational Diagnosis," *Management Science* (30:7), pp. 868–882 (doi: 10.2307/2631652).

Borcard, D., Gillet, F., and Legendre, P. 2011. *Numerical Ecology with R*, New York, NY: Springer New York (available at http://link.springer.com/10.1007/978-1-4419-7976-6).

Brickey, J., Walczak, S., and Burgess, T. 2010. "A Comparative Analysis of Persona Clustering Methods.," in *AMCIS 2010 Proceedings*, p. 217 (available at http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1213&context=amcis2010).

Brickey, J., Walczak, S., and Burgess, T. 2012. "Comparing Semi-Automated Clustering Methods for Persona Development," *IEEE Transactions on Software Engineering* (38:3), pp. 537–546 (doi: 10.1109/TSE.2011.60).

Broschinsky, D., and Baker, L. 2008. "Using Persona with XP at LANDesk Software, an Avocent Company," in *Agile, 2008. AGILE '08. Conference*, Presented at the Agile, 2008. AGILE '08. Conference, , August, pp. 543–548 (doi: 10.1109/Agile.2008.91).

Brown, A. D. 2000. "Making Sense of Inquiry Sensemaking," *Journal of Management Studies* (37:1), p. no–no (doi: 10.1111/1467-6486.00172).

Brown, A. D., Stacey, P., and Nandhakumar, J. 2008. "Making sense of sensemaking narratives," *Human Relations* (61:8), pp. 1035–1062 (doi: 10.1177/0018726708094858).

Buhrmester, M., Kwang, T., and Gosling, S. D. 2011. "Amazon's Mechanical Turk A New Source of Inexpensive, Yet High-Quality, Data?," *Perspectives on Psychological Science* (6:1), pp. 3–5 (doi: 10.1177/1745691610393980).

Bundy, J., and Pfarrer, M. D. 2015. "A Burden of Responsibility: The Role of Social Approval at the Onset of a Crisis," *Academy of Management Review* (40:3), pp. 345–369 (doi: 10.5465/amr.2013.0027).

Burton-Jones, A., McLean, E. R., and Monod, E. 2014. "Theoretical perspectives in IS research: from variance and process to conceptual latitude and conceptual fit," *European Journal of Information Systems* (24:6), pp. 664–679 (doi: 10.1057/ejis.2014.31).

Butcher, K. R., and Sumner, T. 2011. "Self-Directed Learning and the Sensemaking Paradox," *Human–Computer Interaction* (26:1-2), pp. 123–159 (doi: 10.1080/07370024.2011.556552).

Campagnolo, G. M., Pollock, N., and Williams, R. 2015. "Technology as we do not know it: The extended practice of global software development," *Information & Organization* (25:3), pp. 150–159 (doi: 10.1016/j.infoandorg.2015.06.001).

Casler, K., Bickel, L., and Hackett, E. 2013. "Separate but equal? A comparison of participants and data gathered via Amazon's MTurk, social media, and face-to-face behavioral testing," *Computers in Human Behavior* (29:6), pp. 2156–2160 (doi: 10.1016/j.chb.2013.05.009).

Cecez-Kecmanovic, D., Galliers, R. D., Henfridsson, O., Newell, S., and Vidgen, R. 2014. "The sociomateriality of information systems: current status, future directions," *MIS Quarterly* (38:3), pp. 809–830.

Cenfetelli, R. T., and Bassellier, G. 2009. "Interpretation of Formative Measurement in Information Systems Research," *MIS Quarterly* (33:4), pp. 689–707.

Chang, Y., Lim, Y., and Stolterman, E. 2008. "Personas: From Theory to Practices," in *Proceedings of the 5th Nordic Conference on Human-computer Interaction: Building Bridges*NordiCHI '08, New York, NY, USA: ACM, pp. 439–442 (doi: 10.1145/1463160.1463214).

Charmaz, K. 2006. "Coding in Grounded Theory Practice," in *Constructing grounded theory*, SAGE.

Chemero, A. 2003. "An Outline of a Theory of Affordances," *Ecological Psychology* (15:2), pp. 181–195 (doi: 10.1207/S15326969ECO1502_5).

Chung, C., and Ackerman, D. 2015. "Student Reactions to Classroom Management Technology: Learning Styles and Attitudes Toward Moodle," *Journal of Education for Business* (90:4), pp. 217–223 (doi: 10.1080/08832323.2015.1019818).
Churchill, G. A. 1979. "A Paradigm for Developing Better Measures of Marketing Constructs," *Journal of Marketing Research* (16:1), pp. 64–73 (doi: 10.2307/3150876).
Collier, A. 1994. "Critical realism: an introduction to Roy Bhaskar's philosophy," (available at http://philpapers.org/rec/COLCRA).
Columbus, L. 2013. "Personas Are The Future of Enterprise Apps: Lessons Learned From Scribe Software," *Forbes* (available at http://www.forbes.com/sites/louiscolumbus/2013/03/29/personas-are-the-future-of-enterprise-apps-lessons-learned-from-scribe-software/; retrieved May 30, 2016).
Compeau, D., Marcolin, B., Kelley, H., and Higgins, C. 2012. "Research Commentary—Generalizability of Information Systems Research Using Student Subjects—A Reflection on Our Practices and Recommendations for Future Research," *Information Systems Research* (23:4), pp. 1093–1109 (doi: 10.1287/isre.1120.0423).
Cooper, A. 1999. *The inmates are running the asylum:[Why high-tech products drive us crazy and how to restore the sanity]* (Vol. 261), Sams Indianapolis (available at http://itu.dk/people/russel/B%F8ger/Pearson.-.The.Inmates.Are.Running.the.Asylum.pdf).
Costall, A. 1995. "Socializing Affordances," *Theory & Psychology* (5:4), pp. 467 –481 (doi: 10.1177/0959354395054001).
Davidson, E. 2006. "A Technological Frames Perspective on Information Technology and Organizational Change," *The Journal of Applied Behavioral Science* (42:1), pp. 23–39 (doi: 10.1177/0021886305285126).
DeSanctis, G., and Poole, M. S. 1994. "Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory," *Organization Science* (5:2), pp. 121–147.
Ding, W. W. 2011. "The Impact of Founders' Professional-Education Background on the Adoption of Open Science by For-Profit Biotechnology Firms," *Management Science* (57:2), pp. 257–273 (doi: 10.1287/mnsc.1100.1278).
Dobrev, S. D., Kim, T.-Y., and Carroll, G. R. 2002. "The Evolution of Organizational Niches: U.S. Automobile Manufacturers, 1885-1981," *Administrative Science Quarterly* (47:2), pp. 233–264 (doi: 10.2307/3094805).
Dobson, P. J. 2001. "The Philosophy of Critical Realism—An Opportunity for Information Systems Research," *Information Systems Frontiers* (3:2), pp. 199–210 (doi: 10.1023/A:1011495424958).
Dobson, P., Jackson, P., and Gengatharen, D. 2013. "Explaining Broadband Adoption in Rural Australia: Modes of Reflexivity and the Morphogenetic Approach," *MIS Quarterly* (37:3), pp. 965–991.
Drazin, R., Glynn, M. A., and Kazanjian, R. K. 1999. "Multilevel Theorizing about Creativity in Organizations: A Sensemaking Perspective," *The Academy of Management Review* (24:2), pp. 286–307 (doi: 10.2307/259083).
Dunford, R., and Jones, D. 2000. "Narrative in Strategic Change," *Human Relations* (53:9), pp. 1207–1226 (doi: 10.1177/0018726700539005).
Dutton, J. E., Ashford, S. J., Lawrence, K. A., and Miner-Rubino, K. 2002. "Red Light, Green Light: Making Sense of the Organizational Context for Issue Selling," *Organization Science* (13:4), pp. 355–369 (doi: 10.1287/orsc.13.4.355.2949).

Eiszler, C. 1983. “Perceptual Preferences as an Aspect of Adolescent Learning Styles,” *Education* (103:3), p. 231.
Ellway, B. P. W., and Walsham, G. 2015. “A doxa-informed practice analysis: reflexivity and representations, technology and action,” *Information Systems Journal* (25:2), pp. 133–160 (doi: 10.1111/isj.12041).
Elton, C. S. 1927. *Animal ecology*, University of Chicago Press (available at http://books.google.ca/books?hl=en&lr=&id=lZvgTuB9Gh4C&oi=fnd&pg=PA1&dq=animal+ecology+elton&ots=MU8ZYOHgiG&sig=0evDAJ0UOujhmLAhpL90m5ldCts).
Faily, S., and Flechais, I. 2011. “Persona Cases: A Technique for Grounding Personas,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*CHI ’11, New York, NY, USA: ACM, pp. 2267–2270 (doi: 10.1145/1978942.1979274).
Faraj, S., and Azad, B. 2012. “The Materiality of Technology: An Affordance Perspective,” in *Materiality and Organizing: Social Interaction in a Technological World*, Oxford University Press, USA.
Faraj, S., Kwon, D., and Watts, S. 2004. “Contested artifact: technology sensemaking, actor networks, and the shaping of the Web browser,” *Information Technology & People* (17:2), pp. 186–209 (doi: 10.1108/09593840410542501).
Felder, R. M., and Spurlin, J. 2005. “Applications, reliability and validity of the index of learning styles,” *International journal of engineering education* (21:1), pp. 103–112.
Fieberg, J. 2007. “Kernel density estimators of home range: smoothing and the autocorrelation red herring,” *Ecology* (88:4), pp. 1059–1066 (doi: 10.1890/06-0930).
Fiss, P. C., and Zajac, E. J. 2006. “The Symbolic Management of Strategic Change: Sensegiving via Framing and Decoupling,” *The Academy of Management Journal* (49:6), pp. 1173–1193 (doi: 10.2307/20159826).
Fleiss, J. L. 1971. “Measuring nominal scale agreement among many raters.,” *Psychological bulletin* (76:5), p. 378.
Fleiss, J. L., Nee, J. C., and Landis, J. R. 1979. “Large sample variance of kappa in the case of different sets of raters.,” *Psychological Bulletin* (86:5), p. 974.
Fulk, J. 1993. “Social Construction of Communication Technology,” *The Academy of Management Journal* (36:5), pp. 921–950 (doi: 10.2307/256641).
Gäre, K., and Melin, U. 2013. “Sociomaterial actors in the assimilation gap: a case study of web service, management and IT-assimilation,” *Information Systems & e-Business Management* (11:4), pp. 481–506 (doi: 10.1007/s10257-012-0205-9).
Gasson, S. 2005. “The dynamics of sensemaking, knowledge, and expertise in collaborative, boundary-spanning design,” *Journal of Computer-Mediated Communication* (10:4), pp. 1–1.
Gause, G. F. 1934. *The struggle for existence*, Williams & Wilkins Co. (available at http://books.google.ca/books?hl=en&lr=&id=v01OToAhJboC&oi=fnd&pg=PA1&dq=the+struggle+of+existence&ots=5kljs8DSSE&sig=CAL2OIhBEPrjie6Mm8mGRVrz-so).
Gaver, W. W. 1991. “Technology affordances,” pp. 79–84.
Gephart, R. P. 1993. “The Textual Approach: Risk and Blame in Disaster Sensemaking,” *The Academy of Management Journal* (36:6), pp. 1465–1514 (doi: 10.2307/256819).
Gephart, R. P. 2004. “Sensemaking and New Media at Work,” *American Behavioral Scientist* (48:4), pp. 479–495 (doi: 10.1177/0002764204270283).

Gersh, J., Lewis, B., Montemayor, J., Piatko, C., and Turner, R. 2006. "Supporting Insight-Based Information Exploration in Intelligence Analysis," *Communications of the ACM* (49:4), pp. 63–68 (doi: 10.1145/1121949.1121984).

Gibson, E. J. 1982. "The Concept of Affordances in Development: The Renascence of Functionalism," in *The Concept of Development*The Minnesota Symposia on Child Psychology (Vol. 15), Lawrence Erlbaum Associates, pp. 55–81.

Gibson, J. J. 1977. "The Theory of Affordances," in *Perceiving, acting, and knowing: toward an ecological psychology*J. B. Robert E Shaw (ed.), Hillsdale, N.J. : Lawrence Erlbaum Associates, pp. pp.67–82 (available at http://hal.archives-ouvertes.fr/hal-00692033).

Gibson, J. J. 1986. *The ecological approach to visual perception*, Lawrence Erlbaum.

Giddens, A. 1984. "Elements of the Theory of Structuration," in *The Constitution of society: Outline of the Theory of Structure, Ed., University of California Press, Berkeley, CA*, pp. 1–40.

Gioia, D. A., and Chittipeddi, K. 1991. "Sensemaking and sensegiving in strategic change initiation," *Strategic Management Journal* (12:6), pp. 433–448 (doi: 10.1002/smj.4250120604).

Gioia, D. A., and Mehra, A. 1996. "Sensemaking in organizations: book review," *The Academy of Management Review* (21:4), pp. 1226–1230 (doi: 10.2307/259169).

Gioia, D. A., and Thomas, J. B. 1996. "Identity, Image, and Issue Interpretation: Sensemaking During Strategic Change in Academia," *Administrative Science Quarterly* (41:3), pp. 370–403 (doi: 10.2307/2393936).

Gioia, D. A., Thomas, J. B., Clark, S. M., and Chittipeddi, K. 1994. "Symbolism and Strategic Change in Academia: The Dynamics of Sensemaking and Influence," *Organization Science* (5:3), pp. 363–383 (doi: 10.2307/2635136).

Godoy, D., and Amandi, A. 2009. "Interest Drifts in User Profiling: A Relevance-Based Approach and Analysis of Scenarios," *The Computer Journal* (52:7), pp. 771–788 (doi: 10.1093/comjnl/bxm107).

Gopal, A., and Prasad, P. 2000. "Understanding GDSS in Symbolic Context: Shifting the Focus from Technology to Interaction," *MIS Quarterly* (24:3), pp. 509–546 (doi: 10.2307/3250972).

Grant, A. M., Dutton, J. E., and Rosso, B. D. 2008. "Giving Commitment: Employee Support Programs and The Prosocial Sensemaking Process," *Academy of Management Journal* (51:5), pp. 898–918 (doi: 10.5465/AMJ.2008.34789652).

Greeno, J. G. 1994. "Gibson's affordances," *Psychological Review* (101:2), pp. 336–342 (doi: 10.1037/0033-295X.101.2.336).

Griffith, T. L. 1999. "Technology features as triggers for sensemaking," *Academy of Management Review* (24:3), pp. 472–488.

Grinnell, J. 1917. *The Niche-Relationships of the California Thrasher*, The Auk (available at http://archive.org/details/jstor-4072271).

Gulliksen, J., Göransson, B., Boivie, I., Blomkvist, S., Persson, J., and Cajander, Å. 2003. "Key principles for user-centred systems design," *Behaviour & Information Technology* (22:6), pp. 397–409 (doi: 10.1080/01449290310001624329).

Hahn, T., Preuss, L., Pinkse, J., and Figge, F. 2014. "Cognitive Frames in Corporate Sustainability: Managerial Sensemaking with Paradoxical and Business Case Frames," *Academy of Management Review* (39:4), pp. 463–487 (doi: 10.5465/amr.2012.0341).

Hallerbach, I., Barrett, M., and Faraj, S. 2013. "Emergence in Nascent Online Communities: An Affordance Perspective," *ICIS 2013 Proceedings* (available at http://aisel.aisnet.org/icis2013/proceedings/ResearchInProgress/83).
Hannan, M. T., and Freeman, J. 1977. "The population ecology of organizations," *American journal of sociology*, pp. 929–964.
Hardesty, D. L. 1975. "The niche concept: suggestions for its use in human ecology," *Human Ecology* (3:2), pp. 71–85.
Harris, S. G. 1994. "Organizational Culture and Individual Sensemaking: A Schema-Based Perspective," *Organization Science* (5:3), pp. 309–321 (doi: 10.2307/2635133).
Hartnett, E. J., Daniel, E. M., and Holti, R. 2012. "Client and consultant engagement in public sector IS projects," *International Journal of Information Management* (32:4), pp. 307–317 (doi: 10.1016/j.ijinfomgt.2012.05.005).
Hayes, A. F. 2009. "Beyond Baron and Kenny: Statistical Mediation Analysis in the New Millennium," *Communication Monographs* (76:4), pp. 408–420 (doi: 10.1080/03637750903310360).
Hayes, A. F. 2013. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*, Guilford Press (available at https://books.google.ca/books?hl=en&lr=&id=iWFSpQFh-y4C&oi=fnd&pg=PP1&dq=Introduction+to+Mediation,+Moderation,+and+Conditional+Process+Analysis&ots=1y20rG4EPY&sig=wwISvZQNKfr6BfYwrPPV2xBFAV0).
Heft, H. 1996. "The ecological approach to navigation: A Gibsonian perspective," *The construction of cognitive maps*, pp. 105–132.
Heft, H. 2003. "Affordances, Dynamic Experience, and the Challenge of Reification," *Ecological Psychology* (15:2), pp. 149–180 (doi: 10.1207/S15326969ECO1502_4).
Helms-Mills, J. 2002. *Making Sense of Organizational Change*, Routledge.
Henfridsson, O. 2000. "Ambiguity in IT adaptation: making sense of First Class in a social work setting," *Information Systems Journal* (10:2), pp. 87–104 (doi: 10.1046/j.1365-2575.2000.00077.x).
Henfridsson, O., and Bygstad, B. 2013. "The Generative Mechanisms of Digital Infrastructure Evolution," *MIS Quarterly* (37:3), pp. 907–A5.
Hill, J. R. 1999. "A Conceptual Framework for Understanding Information Seeking in Open-Ended Information Systems," *Educational Technology Research and Development* (47:1), pp. 5–27 (doi: 10.2307/30220227).
Hill, R. C., and Levenhagen, M. 1995. "Metaphors and Mental Models: Sensemaking and Sensegiving in Innovative and Entrepreneurial Activities," *Journal of Management* (21:6), pp. 1057–1074 (doi: 10.1177/014920639502100603).
Hou, S.-T. 2008. "Triggering the sources and consequences of technology sense-making: A case study on the GPS dispatching system in Taipei," in *4th IEEE International Conference on Management of Innovation and Technology, 2008. ICMIT 2008*, Presented at the 4th IEEE International Conference on Management of Innovation and Technology, 2008. ICMIT 2008, , September, pp. 53 –58 (doi: 10.1109/ICMIT.2008.4654336).
Hsiao, R.-L., Wu, S.-H., and Hou, S.-T. 2008. "Sensitive cabbies: Ongoing sense-making within technology structuring," *Information and Organization* (18:4), pp. 251–279 (doi: 10.1016/j.infoandorg.2008.01.002).

Huff, C., and Tingley, D. 2015. "'Who are these people?' Evaluating the demographic characteristics and political preferences of MTurk survey respondents," *Research & Politics* (2:3), p. 2053168015604648 (doi: 10.1177/2053168015604648).
Hutchby, I. 2001. "Technologies, texts and affordances," *Sociology* (35:02), pp. 441–456.
Hutchinson, G. E. 1973. *The ecological theater and the evolutionary play*, New Haven: Yale University Press.
Ibarra, H., and Andrews, S. B. 1993. "Power, Social Influence, and Sense Making: Effects of Network Centrality and Proximity on Employee Perceptions," *Administrative Science Quarterly* (38:2), pp. 277–303 (doi: 10.2307/2393414).
Im, G., and Rai, A. 2014. "IT-Enabled Coordination for Ambidextrous Interorganizational Relationships," *Information Systems Research* (25:1), pp. 72–92 (doi: 10.1287/isre.2013.0496).
Jacobs, C. D., Steyaert, C., and Überbacher, F. 2013. "Anticipating intended users: prospective sensemaking in technology development," *Technology Analysis & Strategic Management* (25:9), pp. 1027–1043 (doi: 10.1080/09537325.2013.832749).
Jang, J., Dworkin, J., and Hessel, H. 2015. "Mothers' use of information and communication technologies for information seeking," *Cyberpsychology, Behavior, and Social Networking* (18:4), pp. 221–227 (doi: 10.1089/cyber.2014.0533).
Jarvenpaa, S. L. 1989. "The Effect of Task Demands and Graphical Format on Information Processing Strategies," *Management Science* (35:3), pp. 285–303.
Jasperson, J. (Sean), Carter, P. E., and Zmud, R. W. 2005. "A Comprehensive Conceptualization of Post-Adoptive Behaviors Associated with Information Technology Enabled Work Systems," *MIS Quarterly* (29:3), pp. 525–557.
Jensen, T. B., and Kjærgaard, A. 2010. "Using Existing Response Repertoires to Make Sense of Information System Implementation," *Scandinavian Journal of Information Systems* (22:2), pp. 31–47.
Jick, T. D. 1979. "Mixing qualitative and quantitative methods: Triangulation in action," *Administrative Science Quarterly*, pp. 602–611.
Johansson, M., and Messeter, J. 2005. "Present-ing the user: constructing the persona," *Digital Creativity* (16:4), pp. 231–243 (doi: 10.1080/14626260500476606).
Johnson, R. H. 1910. *Determinate evolution in the color-pattern of the lady-beetles*, Washington, D.C., Carnegie Institution of Washington (available at http://archive.org/details/determinateevol00johngoog).
Jones, M. R., and Karsten, H. 2008. "Giddens's structuration theory and information systems research," *MIS Quarterly* (32:1), pp. 127–157.
Karsten, H. 1995. "'It's Like Everyone Working Around the Same Desk': Organisational Readings of Lotus Notes," *Scandinavian Journal of Information Systems* (7:1), pp. 3–32.
Karsten, H., and Laine, A. 2007. "User interpretations of future information system use: A snapshot with technological frames," *International Journal of Medical Informatics* (76, Supplement 1:0), pp. S136–S140 (doi: 10.1016/j.ijmedinf.2006.05.013).
Khoo, H., and Robey, D. 2007. "Deciding to upgrade packaged software: a comparative case study of motives, contingencies and dependencies," *European Journal of Information Systems* (16:5), pp. 555–567 (doi: http://0-dx.doi.org.mercury.concordia.ca/10.1057/palgrave.ejis.3000704).
Kjærgaard, A., Nielsen, P. A., and Kautz, K. 2010. "Making Sense of Software Project Management," *Scandinavian Journal of Information Systems* (22:1), pp. 3–26.

Kozlowski, S. W., and Klein, K. J. 2000. "A multilevel approach to theory and research in organizations: Contextual, temporal, and emergent processes.," in *Multilevel theory, research and methods in organizations: Foundations, extensions, and new directions* (available at http://psycnet.apa.org/psycinfo/2000-16936-001).

Landgren, J. 2005. "Supporting fire crew sensemaking enroute to incidents," *International Journal of Emergency Management* (2:3), pp. 1–1.

Landis, J. R., and Koch, G. G. 1977. "The Measurement of Observer Agreement for Categorical Data," *Biometrics* (33:1), pp. 159–174 (doi: 10.2307/2529310).

Lapointe, L., and Rivard, S. 2005. "A Multilevel Model of Resistance to Information Technology Implementation," *MIS Quarterly* (29:3), p. 6.

Laporte, L., Slegers, K., and De Grooff, D. 2012. "Using Correspondence Analysis to Monitor the Persona Segmentation Process," in *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*NordiCHI '12, New York, NY, USA: ACM, pp. 265–274 (doi: 10.1145/2399016.2399058).

Latour, B. 1992. "Where are the missing masses? Sociology of a few mundane artefacts," in *Shaping Technology, Building Society: Studies in Sociotechnical Change*, Cambridge, MA: MIT Press, pp. 225–258.

Latour, B. 2005. *Reassembling the social: An introduction to actor-network-theory*, Oxford University Press, USA.

Leonardi, P. M. 2011. "When Flexible Routines Meet Flexible Technologies: Affordance, Constraint, and the Imbrication of Human and Material Agencies," *MIS Quarterly* (35:1), pp. 147–167.

Leonardi, P. M. 2013a. "When Does Technology Use Enable Network Change in Organizations? a Comparative Study of Feature Use and Shared Affordances," *MIS Quarterly* (37:3), pp. 749–775.

Leonardi, P. M. 2013b. "Theoretical foundations for the study of sociomateriality," *Information and Organization* (23:2), pp. 59–76 (doi: 10.1016/j.infoandorg.2013.02.002).

Leonardi, P. M., and Barley, S. R. 2010. "What's Under Construction Here? Social Action, Materiality, and Power in Constructivist Studies of Technology and Organizing," *The Academy of Management Annals* (4:1), pp. 1–51 (doi: 10.1080/19416521003654160).

Leonardi, P. M., Nardi, B. A., and Kallinikos, J. (Eds.). 2012. *Materiality and Organizing: Social Interaction in a Technological World*, Oxford University Press.

Levins, R. 1968. *Evolution in Changing Environments: Some Theoretical Explorations*, Princeton University Press.

Lewis, M. O., Mathiassen, L., and Rai, A. 2011. "Scalable growth in IT-enabled service provisioning: a sensemaking perspective," *European Journal of Information Systems* (20:3), pp. 285–302 (doi: 10.1057/ejis201.5).

Lindgren, A., Chen, F., Amdahl, P., and Chaikiat, P. 2007. "Using Personas and Scenarios as an Interface Design Tool for Advanced Driver Assistance Systems," in *Universal Access in Human-Computer Interaction. Ambient Interaction*Lecture Notes in Computer Science, C. Stephanidis (ed.), Springer Berlin Heidelberg, pp. 460–469 (available at http://0-link.springer.com.mercury.concordia.ca/chapter/10.1007/978-3-540-73281-5_49).

Lockett, A., Currie, G., Finn, R., Martin, G., and Waring, J. 2013. "The Influence of Social Position on Sensemaking About Organizational Change," *Academy of Management Journal*, p. amj.2011.0055 (doi: 10.5465/amj.2011.0055).

Long, F. 2009. "Real or imaginary: The effectiveness of using personas in product design," in *Proceedings of the Irish Ergonomics Society Annual Conference*, Irish Ergonomics Society Dublin, pp. 1–10 (available at http://www.frontend.com/products-digital-devices/real-or-imaginary-the-effectiveness-of-using-personas-in-product-design.html).

Louis, M. R. 1980. "Surprise and Sense Making: What Newcomers Experience in Entering Unfamiliar Organizational Settings," *Administrative Science Quarterly* (25:2), pp. 226–251 (doi: 10.2307/2392453).

Lüscher, L. S., and Lewis, M. W. 2008. "Organizational Change and Managerial Sensemaking: Working Through Paradox," *Academy of Management Journal* (51:2), pp. 221–240 (doi: 10.5465/AMJ.2008.31767217).

Maechler, M., original), P. R. (Fortran, original), A. S. (S, original), M. H. (S, maintenance(1999-2000)), K. H. (port to R., Studer, M., and Roudier, P. 2015. *cluster: "Finding Groups in Data": Cluster Analysis Extended Rousseeuw et al.* (available at https://cran.r-project.org/web/packages/cluster/index.html).

Maitlis, S. 2004. "Taking it from the Top: How CEOs Influence (and Fail to Influence) their Boards," *Organization Studies* (25:8), pp. 1275–1311 (doi: 10.1177/0170840604046318).

Maitlis, S. 2005. "The Social Processes of Organizational Sensemaking," *The Academy of Management Journal* (48:1), pp. 21–49 (doi: 10.2307/20159639).

Maitlis, S., and Lawrence, T. B. 2007. "Triggers and Enablers of Sensegiving in Organizations," *The Academy of Management Journal* (50:1), pp. 57–84 (doi: 10.2307/20159841).

Majchrzak, A., Faraj, S., Kane, G. C., and Azad, B. 2013. "The Contradictory Influence of Social Media Affordances on Online Communal Knowledge Sharing," *Journal of Computer-Mediated Communication* (19:1), pp. 38–55 (doi: 10.1111/jcc4.12030).

Ma, J., and LeRouge, C. 2007. "Introducing user profiles and personas into information systems development," in *AMCIS 2007 Proceedings*, Presented at the AMCIS, p. 237 (available at http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1747&context=amcis2007).

Mansour, O., Askenas, L., and Ghazawneh, A. 2013. "Social Media and Organizing – An Empirical Analysis of the Role of Wiki Affordances in Organizing Practices," *ICIS 2013 Proceedings* (available at http://aisel.aisnet.org/icis2013/proceedings/OrganizationIS/9).

March, J. G. 1996. "Continuity and Change in Theories of Organizational Action," *Administrative Science Quarterly* (41:2), pp. 278–287 (doi: 10.2307/2393720).

Markus, M. L. 1994. "Finding a happy medium: Explaining the negative effects of electronic communication on social life at work," *ACM Transactions on Information Systems (TOIS)* (12:2), pp. 119–149.

Markus, M. L., and Silver, M. S. 2008. "A Foundation for the Study of IT Effects: A New Look at DeSanctis and Poole's Concepts of Structural Features and Spirit," *Journal of the Association for Information Systems* (9:10), pp. 609–632.

McDaniel Albritton, W. 2010. "A Multilevel Model Combining Sensemaking and Improvisation Theories for IT and Organizational Change," Presented at the Hawaii International Conference on System Sciences (HICSS), , January, pp. 1 –10 (doi: 10.1109/HICSS.2010.24).

McGinn, J. (Jen), and Kotamraju, N. 2008. "Data-driven Persona Development," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*CHI '08, New York, NY, USA: ACM, pp. 1521–1524 (doi: 10.1145/1357054.1357292).

Mesgari, M., and Azad, B. 2013. "A Selective Review of Affordance Lens for Organization-Technology Research," in *Academy of Management Proceedings* (Vol. 2013), Academy

of Management, p. 14762 (available at http://proceedings.aom.org/content/2013/1/14762.short).
Mesgari, M., and Faraj, S. 2012. "Technology Affordances: The Case of Wikipedia," in *AMCIS 2012 Proceedings*, Presented at the Americas Conference on Information Systems (available at http://aisel.aisnet.org/amcis2012/proceedings/VirtualCommunities/13/).
Mesgari, M., and Okoli, C. 2015. "Ecological Approach to User Sensemaking of Technology," *ICIS 2015 Proceedings* (available at http://aisel.aisnet.org/icis2015/proceedings/HumanBehaviorIS/22).
Mesgari, M., Okoli, C., and Guinea, A. O. de. 2015. "Affordance-based User Personas : A mixed-method Approach to Persona Development," *AMCIS 2015 Proceedings* (available at http://aisel.aisnet.org/amcis2015/AdoptionofIT/GeneralPresentations/26).
Messick, S., and others. 1976. "Personality consistencies in cognition and creativity," *Individuality in learning* (4), p. 22.
Miaskiewicz, T., Grant, S. J., and Kozar, K. A. 2009. "A preliminary examination of using personas to enhance user-centered design," in *AMCIS 2009 Proceedings*, Presented at the AMCIS, p. 697 (available at http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1680&context=amcis2009).
Miaskiewicz, T., Sumner, T., and Kozar, K. A. 2008. "A Latent Semantic Analysis Methodology for the Identification and Creation of Personas," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*CHI '08, New York, NY, USA: ACM, pp. 1501–1510 (doi: 10.1145/1357054.1357290).
Michaels, C. F. 2000. "Information, Perception, and Action: What Should Ecological Psychologists Learn From Milner and Goodale (1995)?," *Ecological Psychology* (12:3), pp. 241–258 (doi: 10.1207/S15326969ECO1203_4).
Michaels, C. F. 2003. "Affordances: Four Points of Debate," *Ecological Psychology* (15:2), pp. 135–148 (doi: 10.1207/S15326969ECO1502_3).
Michaels, C. F., Withagen, R., Jacobs, D. M., Zaal, F. T. J. M., and Bongers, R. M. 2001. "Information, perception, and action: A reply to commentators," *Ecological Psychology* (13:3), pp. 227–244.
Mingers, J. 2004. "Real-izing information systems: critical realism as an underpinning philosophy for information systems," *Information and Organization* (14:2), pp. 87–103 (doi: 10.1016/j.infoandorg.2003.06.001).
Mingers, J., Mutch, A., and Willcocks, L. 2013. "Critical Realism in Information Systems Research," *MIS Quarterly* (37:3), pp. 795–802.
Mishra, A. N., and Agarwal, R. 2009. "Technological Frames, Organizational Capabilities, and IT Use: An Empirical Investigation of Electronic Procurement," *Information Systems Research* (21:2), pp. 249–270 (doi: 10.1287/isre.1080.0220).
Moore, G. C., and Benbasat, I. 1991. "Development of an instrument to measure the perceptions of adopting an information technology innovation," *Information Systems Research* (2:3), pp. 192–222.
Moser, C., Fuchsberger, V., and Tscheligi, M. 2011. "Using Probes to Create Child Personas for Games," in *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*ACE '11, New York, NY, USA: ACM, pp. 39:1–39:8 (doi: 10.1145/2071423.2071472).
Mumby, D. K. 1987. "The political function of narrative in organizations," *Communication Monographs* (54:2), pp. 113–127 (doi: 10.1080/03637758709390221).

Nevo, S., and Wade, M. R. 2010. "The Formation and Value of IT-Enabled Resources: Antecedents and Consequences of Synergistic Relationships," (available at http://www.misq.org/cat-articles/the-formation-and-value-of-it-enabled-resources-antecedents-and-consequences-of-synergistic-relationships.html).
Norman, D. 2004. "Affordances and design," *Retrieved April* (19), p. 2007.
Norman, D. A. 1988. *The Psychology of Everyday Things*, Basic Books (AZ).
Norman, D. A. 1999. "Affordance, conventions, and design," *interactions* (6:3), pp. 38–43 (doi: 10.1145/301153.301168).
Norman, D. A. 2002. *The Design of Everyday Things*, Basic Books.
Núñez, J. C., Cerezo, R., and Bernardo, A. 2011. "Implementation of training programs in self-regulated learning strategies in Moodle format: Results of a experience in higher education," *Implementación de programas de entrenamiento en estrategias de autorregulación del aprendizaje en formato Moodle: resultados de una experiencia en enseñanza superior.* (23:2), pp. 274–281.
Okamura, K., Fujimoto, M., Orlikowski, W. J., and Yates, J. 1995. "Helping CSCW applications succeed: The role of mediators in the context of use," *The Information Society* (11:3), pp. 157–172 (doi: 10.1080/01972243.1995.9960190).
Olesen, K. 2014. "Implications of dominant technological frames over a longitudinal period," *Information Systems Journal* (24:3), pp. 207–228 (doi: 10.1111/isj.12006).
Onook Oh, Chanyoung Eom, and Rao, H. R. 2015. "Role of Social Media in Social Change: An Analysis of Collective Sense Making During the 2011 Egypt Revolution," *Information Systems Research* (26:1), pp. 210–223 (doi: 10.1287/isre.2015.0565).
Van Oorschot, I. 2014. "Seeing the case clearly: File-work, material mediation, and visualizing practices in a Dutch criminal court," *Symbolic Interaction* (37:4), pp. 439–457.
Operandi, P. 2014. "Recommendations for Moodle users based on three case studies of university teaching," Presented at the Moodlemoot, Edinburgh (available at https://vimeo.com/141662585).
Orlikowski, W. J. 1992. "The duality of technology: Rethinking the concept of technology in organizations," *Organization science* (3:3), pp. 398–427.
Orlikowski, W. J. 2005. "Material Works: Exploring the Situated Entanglement of Technological Performativity and Human Agency," *Scandinavian Journal of Information Systems* (17), pp. 183–186.
Orlikowski, W. J. 2010. "The sociomateriality of organisational life: considering technology in management research," *Cambridge Journal of Economics* (34:1), pp. 125 –141 (doi: 10.1093/cje/bep058).
Orlikowski, W. J., and Gash, D. C. 1994. "Technological frames: making sense of information technology in organizations," *ACM Trans. Inf. Syst.* (12:2), pp. 174–207 (doi: 10.1145/196734.196745).
Orlikowski, W. J., and Iacono, C. S. 2001. "Research Commentary: Desperately Seeking the 'IT' in IT Research—A Call to Theorizing the IT Artifact," *Information Systems Research* (12:2), pp. 121–134.
Orlikowski, W. J., and Scott, S. V. 2015. "The Algorithm and the Crowd: Considering the Materiality of Service Innovation," *MIS Quarterly* (39:1), pp. 201–216.
Ortiz de Guinea, A., and Markus, M. L. 2009. "Why Break the Habit of a Lifetime? Rethinking the Roles of Intention, Habit, and Emotion in Continuing Information Technology Use," *MIS Quarterly* (33:3), pp. 433–444.

Ortiz de Guinea, A., and Webster, J. 2013. "An Investigation of Information Systems Use Patterns: Technological Events as Triggers, the Effect of Time, and Consequences for Performance," *MIS Quarterly* (37:4), pp. 1165–1188.

Ovaska, P., and Stapleton, L. 2010. "Requirements Engineering During Complex Isd: Case Study of an International Ict Company," *Journal of Information Technology Case & Application Research (Ivy League Publishing)* (12:2), pp. 36–59.

Pagano, U. 1998. "The Origin of Organizational Species," SSRN Scholarly Paper No. ID 217571, , Rochester, NY: Social Science Research Network (available at http://papers.ssrn.com/abstract=217571).

Paul, D. 2006. "Sensemaking in a Distributed Environment," *AMCIS 2006 Proceedings* (available at http://aisel.aisnet.org/amcis2006/197).

Paul, S. A., and Morris, M. R. 2011. "Sensemaking in Collaborative Web Search," *Human–Computer Interaction* (26:1-2), pp. 72–122 (doi: 10.1080/07370024.2011.559410).

Paul, S. A., and Reddy, M. C. 2010. "Understanding together: sensemaking in collaborative information seeking," in *Proceedings of the 2010 ACM conference on Computer supported cooperative work*CSCW '10, New York, NY, USA: ACM, pp. 321–330 (doi: 10.1145/1718918.1718976).

Pearman, P. B., Guisan, A., Broennimann, O., and Randin, C. F. 2008. "Niche dynamics in space and time," *Trends in Ecology & Evolution* (23:3), pp. 149–158 (doi: 10.1016/j.tree.2007.11.005).

Pentland, B. T. 1999. "Building Process Theory with Narrative: From Description to Explanation," *The Academy of Management Review* (24:4), pp. 711–724 (doi: 10.2307/259350).

Petkova, A. P. ., apetkova@sfsu.edu, Rindova, V. P. ., violina.rindova@mccombs.utexas.edu, and Gupta, A. K. ., agupta@rhsmith.umd.edu. 2013. "No News Is Bad News: Sensegiving Activities, Media Attention, and Venture Capital Funding of New Technology Organizations," *Organization Science* (24:3), pp. 865–888 (doi: 10.1287/orsc.1120.0759).

Pirolli, P., and Russell, D. M. 2011. "Introduction to this Special Issue on Sensemaking," *Human–Computer Interaction* (26:1-2), pp. 1–8 (doi: 10.1080/07370024.2011.556557).

Podolny, J. M., and Stuart, T. E. 1995. "A Role-Based Ecology of Technological Change," *American Journal of Sociology* (100:5), pp. 1224–1260.

Polis, G. A. 1984. "Age Structure Component of Niche Width and Intraspecific Resource Partitioning: Can Age Groups Function as Ecological Species?," *The American Naturalist* (123:4), pp. 541–564 (doi: 10.2307/2460997).

Polkinghorne, D. 1988. *Narrative knowing and the human sciences*, Suny Press (available at http://books.google.ca/books?hl=en&lr=&id=co56EVxBV8YC&oi=fnd&pg=PR9&dq=Narrative+knowing+and+the+human+sciences&ots=iEeM5rO4p9&sig=_o-6ndoc90LJg7Li7_wjWqbjzbU).

Prasad, P. 1993. "Symbolic Processes in the Implementation of Technological Change: A Symbolic Interactionist Study of Work Computerization," *The Academy of Management Journal* (36:6), pp. 1400–1429 (doi: 10.2307/256817).

Pruitt, J., and Grudin, J. 2003. "Personas: Practice and Theory," in *Proceedings of the 2003 Conference on Designing for User Experiences*DUX '03, New York, NY, USA: ACM, pp. 1–15 (doi: 10.1145/997078.997089).

Rahimi, M., and Cleland-Huang, J. 2014. "Personas in the middle: automated support for creating personas as focal points in feature gathering forums," ACM Press, pp. 479–484 (doi: 10.1145/2642937.2642958).
Rasmussen, J., and Vicente, K. J. 1989. "Coping with human errors through system design: implications for ecological interface design," *International Journal of Man-Machine Studies* (31:5), pp. 517–534 (doi: 10.1016/0020-7373(89)90014-X).
Ravishankar, M. n., and Pan, S. L. 2013. "Examining the influence of modularity and knowledge management (KM) on dynamic capabilities: Insights from a call center," *International Journal of Information Management* (33:1), pp. 147–159 (doi: 10.1016/j.ijinfomgt.2012.08.003).
R. Core Team. 2015. *R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria* (available at https://www.r-project.org/).
Reyes, V. C. J., and Kheng, C. C. S. 2015. "School stakeholders' experience with navigating ICT policy reforms in Singapore," *International Journal of Information and Communication Technology Education* (11:4), pp. 83–96 (doi: 10.4018/IJICTE.2015100106).
Robey, D., Anderson, C., and Raymond, B. 2013. "Information Technology, Materiality, and Organizational Change: A Professional Odyssey," *Journal of the Association for Information Systems* (14:7), pp. 379–398.
Rose, J., Jones, M., and Truex, D. 2005. "Socio-Theoretic Accounts of IS: The Problem of Agency," *Scandinavian Journal of Information Systems* (17:1) (available at http://aisel.aisnet.org/sjis/vol17/iss1/8).
Rose, J., and Kræmmergaard, P. 2006. "ERP systems and technological discourse shift: Managing the implementation journey," *International Journal of Accounting Information Systems* (7:3), pp. 217–237 (doi: 10.1016/j.accinf.2006.06.003).
Ross, L. 1977. "The intuitive psychologist and his shortcomings: Distortions in the attribution process," *Advances in experimental social psychology* (10), pp. 173–220.
Rouleau, L. 2005. "Micro-Practices of Strategic Sensemaking and Sensegiving: How Middle Managers Interpret and Sell Change Every Day*," *Journal of Management Studies* (42:7), pp. 1413–1441 (doi: 10.1111/j.1467-6486.2005.00549.x).
Savoli, A. 2014. "Studying IT Effects Via Functional Affordances," (available at http://biblos.hec.ca/biblio/theses/2014NO7.PDF).
Savoli, A., and Barki, H. 2013. "Functional Affordance Archetypes: a New Perspective for Examining the Impact of IT Use on Desirable Outcomes," *ICIS 2013 Proceedings* (available at http://aisel.aisnet.org/icis2013/proceedings/ResearchInProgress/110).
Schot, J., and Geels, F. W. 2007. "Niches in evolutionary theories of technical change: A critical survey of the literature," *Journal of Evolutionary Economics* (17:5), pp. 605–622 (doi: http://0-dx.doi.org.mercury.concordia.ca/10.1007/s00191-007-0057-5).
Scott, M. B., and Lyman, S. M. 1968. "Accounts," *American Sociological Review* (33:1), pp. 46–62 (doi: 10.2307/2092239).
Seidel, S., Recker, J., and vom Brocke, J. 2013. "Sensemaking and Sustainable Practicing: Functional Affordances of Information Systems in Green Transformations," *MIS Quarterly* (37:4), pp. 1275–A10.
Al-Shamri, M. Y. H. 2016. "User profiling approaches for demographic recommender systems," *Knowledge-Based Systems* (100), pp. 175–187 (doi: 10.1016/j.knosys.2016.03.006).
Shoib, G., and Nandhakumar, J. 2003. "Cross-cultural IS adoption in multinational corporations," *Information Technology for Development* (10:4), pp. 249–260.

Siino, R. M., and Hinds, P. J. 2005. "Robots, Gender Sensemaking: Sex Segregation #8217;s Impact On Workers Making Sense Of a Mobile Autonomous Robot," in *Proceedings of the 2005 IEEE International Conference on Robotics and Automation, 2005. ICRA 2005*, Presented at the Proceedings of the 2005 IEEE International Conference on Robotics and Automation, 2005. ICRA 2005, , April, pp. 2773 – 2778 (doi: 10.1109/ROBOT.2005.1570533).

Sinha, R. 2003. "Persona development for information-rich domains," in *CHI'03 extended abstracts on Human factors in computing systems*, ACM, pp. 830–831 (available at http://dl.acm.org/citation.cfm?id=766017).

Smith, M. L. 2006. "Overcoming theory-practice inconsistencies: Critical realism and information systems research," *Information and Organization* (16:3), pp. 191–211 (doi: 10.1016/j.infoandorg.2005.10.003).

Sneddon, J. N., Soutar, G. N., and Mazzarol, T. 2009. "On-farm innovation in the Australian wool industry: a sensemaking perspective," *Experimental Agriculture* (45:03), pp. 295–312 (doi: 10.1017/S0014479709007881).

Snell, R. S. 2002. "The learning organization, sensegiving and psychological contracts: A Hong Kong case," *Organization Studies* (23:4), pp. 549–569.

Sonenshein, S. 2007. "The role of construction, intuition, and justification in responding to ethical issues at work: The sensemaking-intuition model," *Academy of Management Review* (32:4), pp. 1022–1040 (doi: 10.5465/AMR.2007.26585677).

Songqi Liu, Mo Wang, Bamberger, P., Junqi Shi, and Bacharach, S. B. 2015. "The Dark Side of Socialization: A Longitudinal Investigation of Newcomer Alcohol Use," *Academy of Management Journal* (58:2), pp. 334–355 (doi: 10.5465/amj.2013.0239).

Stanton, J. M., Sinar, E. F., Balzer, W. K., and Smith, P. C. 2002. "Issues and Strategies for Reducing the Length of Self-Report Scales," *Personnel Psychology* (55:1), pp. 167–194 (doi: 10.1111/j.1744-6570.2002.tb00108.x).

Stigliani, I., and Ravasi, D. 2012. "Organizing Thoughts and Connecting Brains: Material Practices and the Transition from Individual to Group-Level Prospective Sensemaking," *Academy of Management Journal* (55:5), pp. 1232–1259 (doi: 10.5465/amj.2010.0890).

Strong, D. M., Johnson, S. A., Tulu, B., Trudel, J., Volkoff, O., Pelletier, L. R., Bar-On, I., and Garber, L. 2014. "A Theory of Organization-EHR Affordance Actualization," *Journal of the Association for Information Systems* (15:2), pp. 53–85.

Su, N. 2015. "Cultural Sensemaking in Offshore Information Technology Service Suppliers: A Cultural Frame Perspective," *MIS Quarterly* (39:4), pp. 959–983.

Sun, H. 2012. "Understanding user revisions when using information system features: Adaptive system use and triggers," *MIS Quarterly* (36:2), pp. 453–478.

Svejvig, P., and Jensen, T. B. 2013. "Making sense of enterprise systems in institutions: a case study of the re-implementation of an accounting system," *Scandinavian Journal of Information Systems* (25:1), pp. 3–35.

Swaine, M. D., and Whitmore, T. C. 1988. "On the definition of ecological species groups in tropical rain forests," *Vegetatio* (75:1-2), pp. 81–86 (doi: 10.1007/BF00044629).

Tallon, P. P. 2014. "Do you see what I see? The search for consensus among executives' perceptions of IT business value," *European Journal of Information Systems* (23:3), pp. 306–325 (doi: 10.1057/ejis.2013.2).

Tallon, P. P., and Kraemer, K. L. 2007. "Fact or Fiction? A Sensemaking Perspective on the Reality Behind Executives' Perceptions of IT Business Value," *Journal of Management Information Systems* (24:1), pp. 13–54.
Turvey, M. T. 1992. "Affordances and Prospective Control: An Outline of the Ontology," *Ecological Psychology* (4:3), pp. 173–187 (doi: 10.1207/s15326969eco0403_3).
Vaast, E. 2007. "Danger is in the eye of the beholders: Social representations of Information Systems security in healthcare," *The Journal of Strategic Information Systems* (16:2), pp. 130–152 (doi: 10.1016/j.jsis.2007.05.003).
Vaast, E., and Walsham, G. 2005. "Representations and actions: the transformation of work practices with IT use," *Information and Organization* (15:1), pp. 65–89 (doi: 10.1016/j.infoandorg.2004.10.001).
Valen, L. V. 1976. "Ecological Species, Multispecies, and Oaks," *Taxon* (25:2/3), pp. 233–239 (doi: 10.2307/1219444).
Vandermeer, J. H. 1972. "Niche Theory," *Annual Review of Ecology and Systematics* (3), pp. 107–132 (doi: 10.2307/2096844).
Venkatesh, V., Morris, M. G., Davis, G. B., and Davis, F. D. 2003. "User Acceptance of Information Technology: Toward a Unified View," *MIS Quarterly* (27:3), pp. 425–478.
Vicente, K. J., and Rasmussen, J. 1990. "The Ecology of Human-Machine Systems II: Mediating 'Direct Perception' in Complex Work Domains," *Ecological Psychology* (2:3), pp. 207–249 (doi: 10.1207/s15326969eco0203_2).
Vicente, K. J., and Rasmussen, J. 1992. "Ecological interface design: theoretical foundations," *IEEE Transactions on Systems, Man and Cybernetics* (22:4), pp. 589 –606 (doi: 10.1109/21.156574).
Vigentini, L. 2009. "Using learning technology in university courses: do styles matter?," *Multicultural Education & Technology Journal* (3:1), pp. 17–32 (doi: http://0-dx.doi.org.mercury.concordia.ca/10.1108/17504970910951129).
Volkoff, O., and Strong, D. 2013. "Critical Realism and Affordances: Theorizing IT-Associated Organizational Change Processes," *MIS Quarterly* (37:3), pp. 819–834.
Wahlström, M., Salovaara, A., Salo, L., and Oulasvirta, A. 2011. "Resolving Safety-Critical Incidents in a Rally Control Center," *Human–Computer Interaction* (26:1-2), pp. 9–37 (doi: 10.1080/07370024.2011.556541).
Weaver, C. K., Zorn, T., and Richardson, M. 2010. "Goods Not Wanted," *Information, Communication & Society* (13:5), pp. 696–721 (doi: 10.1080/13691180903410535).
Weick, K. E. 1969. *The social psychology of organizing*, Addison-Wesley Pub. Co. (Reading, Mass) (available at http://www.getcited.org/pub/101515705).
Weick, K. E. 1979. *The social psychology of organizing*, Random House.
Weick, K. E. 1988. "Enacted Sensemaking in Crisis Situations," *Journal of Management Studies* (25:4), pp. 305–317 (doi: 10.1111/j.1467-6486.1988.tb00039.x).
Weick, K. E. 1990. "Technology as equivoque: Sensemaking in new technologies," in *Technology and organizations*The Jossey-Bass management series., San Francisco, CA, US: Jossey-Bass, pp. 1–44.
Weick, K. E. 1995. *Sensemaking in organizations* (Vol. 3), Sage Publications, Incorporated (available at http://books.google.ca/books?hl=en&lr=&id=nz1RT-xskeoC&oi=fnd&pg=PR7&dq=sensemaking+in+organizations&ots=zF2nzbgr8l&sig=tlc1tqP_fEmtEhUbO_1FJPovP24).
Weick, K. E. 2000. *Making Sense of the Organization* (1st ed.), Wiley-Blackwell.

Weick, K. E., and Roberts, K. H. 1993. "Collective Mind in Organizations: Heedful Interrelating on Flight Decks," *Administrative Science Quarterly* (38:3), pp. 357–381 (doi: 10.2307/2393372).

Weick, K. E., Sutcliffe, K. M., and Obstfeld, D. 2005. "Organizing and the Process of Sensemaking," *Organization Science* (16:4), pp. 409–421 (doi: 10.1287/orsc.1050.0133).

Whiteman, G., and Cooper, W. H. 2011. "Ecological Sensemaking," *Academy of Management Journal* (54:5), pp. 889–911 (doi: 10.5465/amj.2008.0843).

Wickham, H. 2007. "Reshaping Data with the reshape Package | Wickham | Journal of Statistical Software," *Journal of Statistical Software* (21:12), pp. 1–20.

Wickham, H., and Chang, W. 2015. *ggplot2: An Implementation of the Grammar of Graphics* (available at https://cran.r-project.org/web/packages/ggplot2/index.html).

Wu, A., Convertino, G., Ganoe, C., Carroll, J. M., and Zhang, X. (Luke). 2013. "Supporting collaborative sense-making in emergency management through geo-visualization," *International Journal of Human-Computer Studies* (71:1), pp. 4–23 (doi: 10.1016/j.ijhcs.2012.07.007).

Wu, J., and Lederer, A. 2009. "A Meta-Analysis of the Role of Environment-Based Voluntariness in Information Technology Acceptance," *MIS Quarterly* (33:2), pp. 419–432.

Yang, Z., Kankanhalli, A., Ng, B.-Y., and Koo, K. 2013. "Investigating Mobile Messaging in Healthcare Organizations: A Sensemaking Perspective," *ICIS 2013 Proceedings* (available at http://aisel.aisnet.org/icis2013/proceedings/ResearchInProgress/13).

Yu Tong, Swee-Lin Tan, S., and Hock-Hai Teo. 2015. "The Road to Early Success: Impact of System Use in the Swift Response Phase," *Information Systems Research* (26:2), pp. 418–436 (doi: 10.1287/isre.2015.0578).

Zamani, E., Giaglis, G., and Pouloudi, N. 2013. "A Sensemaking Approach to Tablet Users' Accommodating Practices," *ICIS 2013 Proceedings* (available at http://aisel.aisnet.org/icis2013/proceedings/HumanBehavior/16).

Zammuto, R. F., Griffith, T. L., Majchrzak, A., Dougherty, D. J., and Faraj, S. 2007. "Information technology and the changing fabric of organization," *Organization Science* (18:5), p. 749.

Zheng, Y., and Yu, A. 2016. "Affordances of social media in collective action: the case of Free Lunch for Children in China," *Information Systems Journal* (26:3), pp. 289–313 (doi: 10.1111/isj.12096).

Appendices

APPENDIX 2-1. PILOT STUDY

Extract from: Mesgari, Mostafa and Chitu Okoli (2015). Ecological Approach to Technology Sensemaking. Proceedings of the International Conference on Information Systems. *Fort Worth, USA. December 13-16, 2015.*

Since February 2015, we conducted a pilot study to evaluate affordance perceptions of students using Moodle. The pilot study is focused on proposition 1 of the framework (relationship between affordances and user species); we will extend it later to include the other propositions too. Please note that the "Affordances Extraction" and "User Species and Technoniche" steps are further described in detail in a distinct but somewhat related study (Mesgari et al. 2015); what follows is an abbreviated description of the procedure we followed.

Affordances Extraction: To recruit experienced users, we solicited about 400 undergraduate students of a North American university by email to apply for an interview session about their experiences with Moodle, with an offer of $10 compensation. 13 students applied, and we selected five well-experienced applicants for recorded interviews that took between 30 to 50 minutes each. The semi-structured interviews featured open questions about their experiences on Moodle.

The interviews were transcribed and coded into every possible action, task, and purpose the interviewees were describing. Next, the coded actions and behaviors were grouped into functional groups to facilitate meaningful affordance extraction. Five affordances were extracted:

- **Content Access:** Action possibilities enabling the students to access any course content that they need; these possibilities give the students read-only access to the course-related material
- **Submission:** Action possibilities enabling the students to submit their work, answers, ideas, which might or might not receive subsequent feedback
- **Communication:** Action possibilities enabling the students to communicate and share their ideas, opinion, and questions with the teacher, teaching assistants or fellow

classmates; or to acquire awareness of what the teacher, teaching assistants or classmates communicated or shared; both parties have the chance to express themselves and engage in two-way interaction

- **Practice:** Action possibilities enabling the students to practice what they have already learned about the course material
- **Feedback:** Action possibilities enabling the students to get feedback on their learning, participation, submitted work, or status or progress in the course

Students' Affordance Perceptions of Moodle: We followed the instructions provided by Churchill (1979) and Moore and Benbasat (1991) to develop and evaluate the survey. First, we drew from the interview data to generate items based on how students described their perceptions of the five affordances. Then we did a simple card sorting exercise and improved the items accordingly.

We invited 230 students to complete the survey and grant us permission to match their responses to their Moodle log data. 71 students participated. 8 surveys were not usable, so we analyzed the data for 63 participants for which we had both survey and Moodle log data. The Cronbach's alphas for the items measuring each affordance were above 0.7, which is acceptable reliability. Confirmatory factor analysis was used to evaluate the discriminant validity of the concept measures. While most items loaded well on their respective constructs, some (mostly for Content Access and Feedback) did not properly load; we will revisit these for the full study.

User Species and Technoniches: First, a card sorting exercise was employed to understand how user actions on Moodle actualized the five major affordances identified from the interviews. A list of 36 different actions was extracted from the student log data. We conducted two rounds of card sorting where we asked 4 experienced student users, different 4 for each round, to sort each of the 36 identified user actions into one of the five identified affordance categories. The first round resulted in a satisfactory inter-rater reliability, Fleiss' kappa, of 0.721; a kappa higher than 0.65 can be considered acceptable (Moore and Benbasat 1991). The first round of card sorting resulted in three changes to the actions and affordances. The second round resulted in an improved kappa of 0.871, with no individual affordance having agreement lower than 0.82, which demonstrated substantial agreement between the four students. Thus, no further rounds of

card sorting were needed. Table 2-1-1 displays the final list of which actions corresponded to each affordance.

Table 2-1-1. Card sorting exercise results: actions that support each affordance

Affordances	Moodle Actions that Actualize the Affordances
Content Access	assign view all; assign view before duedate; book view all; course view; folder view; folder view all; imscp view all; lti launch; lti view; lti view all; page view; page view all; quiz view all; resource view; resource view all; url view; url view all
Submission	assign submit; assign view submit assignment form; quiz close attempt
Communication	forum add discussion; forum add post; forum subscribe; forum unsubscribe; forum update post; forum view discussion; forum view forum; forum view forums; user view
Practice	quiz attempt; quiz continue attempt; quiz view
Feedback	assign view after duedate; quiz review; quiz view summary

In the second step of identifying user species, R version 3.2.1 was used including its base package (R. Core Team 2015), cluster package (Maechler et al. 2015), and ggplot2 package (Wickham and Chang 2015) to conduct hierarchical clustering, an appropriate clustering method for smaller samples, and visualize the cluster data. Our dataset included more than 65,000 actions (user log records) conducted by 63 students (after outlier removal). The agglomerative hierarchical clustering procedure used in this study starts with one cluster for each data point and then computes the closest clusters and merges them into one cluster. This process of agglomeration continues until it gets to one general cluster including all data points. We employed a clustering method based on between-group linkages in which the average distance between each two members of every two clusters are computed, and the two groups with the smallest average distance are merged. Furthermore, we chose the Euclidean distance measure because our goal is to identify species whose use of technology corresponds to their perceptions. Thus, we expect that the level of affordance actualization corresponds to the level of affordance perception.

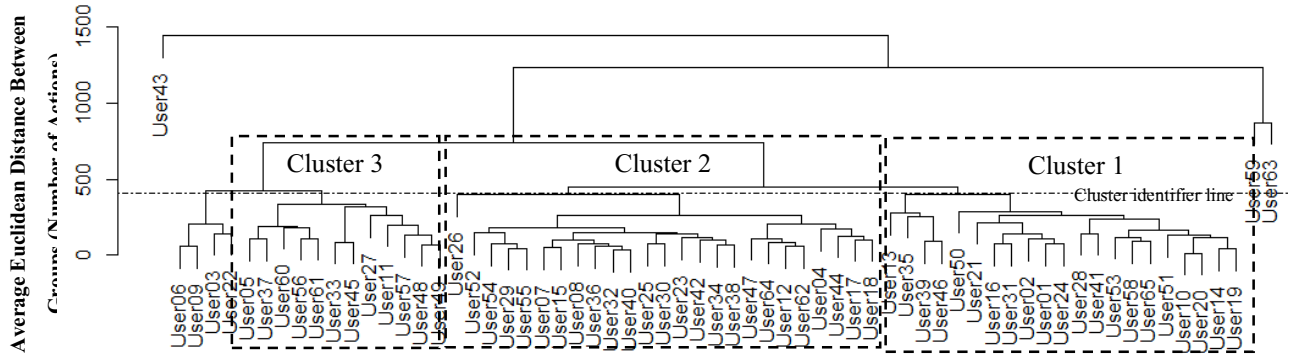

Figure 2-1-1. Dendrogram from Hierarchical Cluster Analysis

Figure 2-1-1 is the resulting dendrogram. We removed the three singleton clusters on the far right as outliers. We chose four as the number of clusters, one of which has only four members, so we removed it from the clusters because it does not represent a meaningfully large enough cluster. So, three clusters identified on the dendrogram represent three species of students adapting differently to Moodle. Figure 2-1-2 depicts the technoniches of the three species; it illustrates that Species 3 (S3) is much more dependent on Practice and Content Access affordances than other species. Species 1 (S1) is least dependent on Practice affordance, while most dependent on Communication affordance. Species 2 (S2) is mildly dependent on Practice affordance while minimally dependent on Content Access affordance.

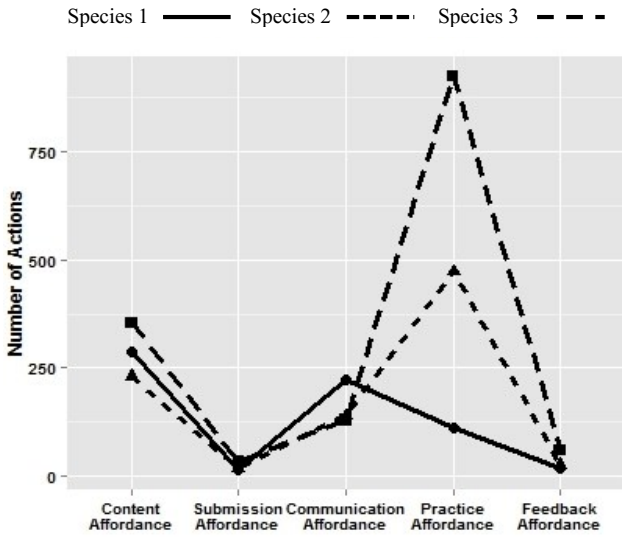

Figure 2-1-2. Average affordance actualization (user logs)

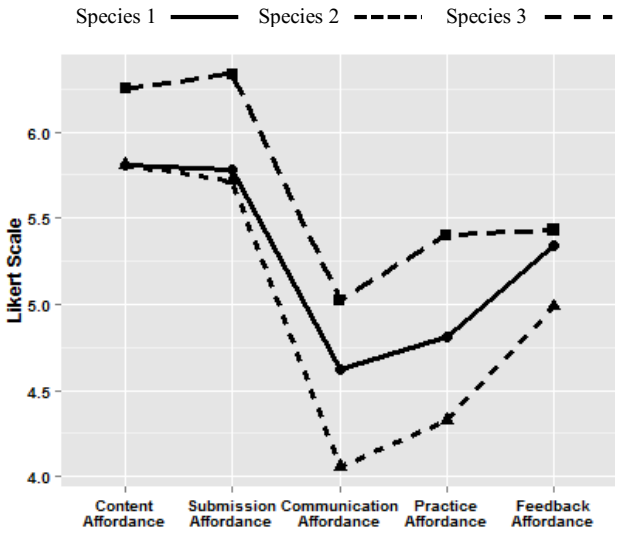

Figure 2-1-3. average affordance perception (survey responses)

We used ANOVA to test if the user species identified by hierarchical clustering actualized affordances at significantly different levels from each other. Specifically, for each affordance actualized, we tested if the average number of actions of the three identified clusters are equal. This hypothesis was rejected for all the five affordance actualizations (see Table 2-1-2), meaning that, for each affordance actualization, at least two of the three clusters are quite different. Two-by-two comparisons using Tukey HSD tests showed that most of the comparisons were significant (see Table 2-1-4). It should be noted that, considering the pilot nature of the study and the small sample size (56 students of the three clusters), we tested all hypotheses at 0.10 level of significance. All in all, the three clusters are representative of three distinct species having significantly different adaptation to Moodle.

To provide further understanding about the three species and their adaptation to various affordances of Moodle, we use the data visualization technique called Kernel Density Estimation, the popular technique in ecology to analyze the distribution of the three species over each affordance (Fieberg 2007). It estimates the probability of occurring data points (students) at various levels of resource consumption (affordance actualization). Figure 2-1-4 visualizes expected distribution of student user species for each Moodle affordance, using R, ggplot2 package. Consistent with the findings of Tables 2-1-2 and 2-1-4, while the communication affordance hardly can differentiate the three species, the practice affordance clearly distinguishes the three species.

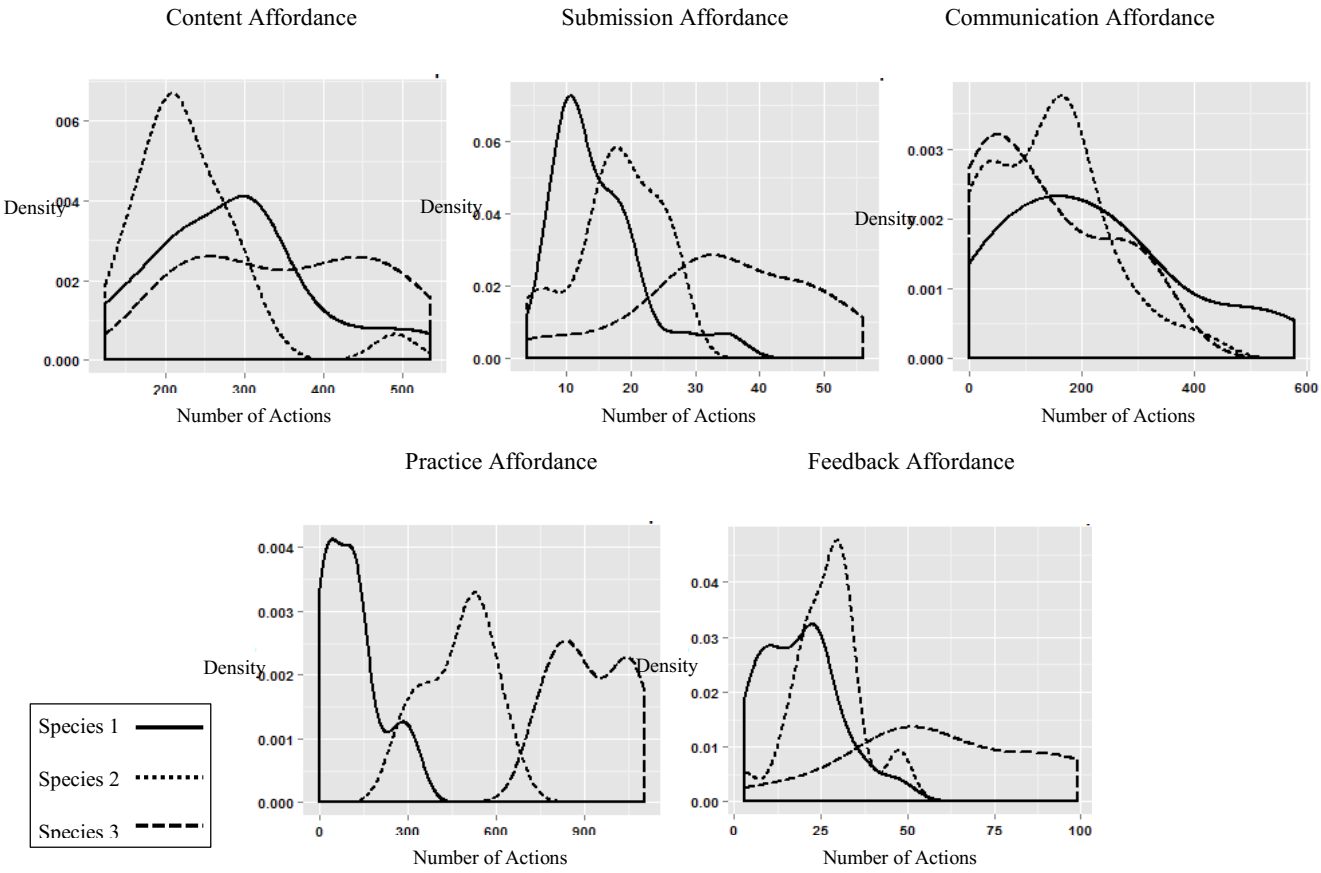

Figure 2-1-4. Visualizing species distribution over actualization of each affordance using Kernel Density Estimation (user logs)

Evaluating the relations: Figure 2-1-3 depicts the average affordance perceptions for each species. We used ANOVA to test if the three clusters (species) demonstrated different perceptions of the five affordances. The F test examined if the averages of the affordance perceptions for the three clusters were equal. Table 2-1-3 shows that for three of the five affordance perceptions, the three clusters demonstrate somewhat different perceptions; that is, the three clusters showed some difference in three of the affordance perceptions. Two-by-two comparisons using Tukey HSD test demonstrate significant differences in sensemaking in regard to three of the affordances (see Table 2-1-5). S1 and S3 perceive 3 Moodle affordances at significantly different levels consistent with their actualization of those affordances. S1 and S2 are not different in any of the affordance perceptions; this is mostly consistent with them not being significantly different in their affordance actualizations. None of the species are

differentiated on affordance perceptions of content access and feedback. This might partly refer to the issues of the survey items of these two concepts.

Table 2-1-2. ANOVA results for mean difference in affordance actualization (log data)

Affordance Actualization	Mean (S1)	Mean (S2)	Mean (S3)	F	Sig.
Content Access	287	231.5	354.25	6.32	.003
Submission	14.86	17.82	34.58	20.57	.000
Communication	222.05	139.55	129.33	2.723	.075
Practice	111.1	471.95	923.08	203.43	.000
Feedback	19	26.95	60.17	26.98	.000

Sample size: 56 Significance level: 0.10

Table 2-1-3. ANOVA results for mean difference in affordance perceptions (survey data)

Affordance Perception	Mean (S1)	Mean (S2)	Mean (S3)	F	Sig.
Content Access	5.8095	5.81	6.2492	1.47	.240
Submission	5.781	5.7182	6.3333	3.02	.057
Communication	4.6252	4.0541	5.0233	2.90	.064
Practice	4.8095	4.3273	5.4	5.63	.006
Feedback	5.3395	4.9845	5.43	1.12	.333

Sample size: 56 Significance level: 0.10

Table 2-1-4. Tukey HSD test result for mean comparisons of affordance actualization (log data)

Affordance Actualization	(I) Cluster	(J) Cluster	Mean Difference (I-J)	Std. Error	Sig.
Content Access	S1	S2	55.500	29.582	.156
		S3	-67.250	35.089	.144
	S2	**S3**	**-122.750***	**34.798**	**.003**
Submission	**S1**	S2	-2.961	2.693	.519
		S3	**-19.726***	**3.195**	**.000**
	S2	**S3**	**-16.765***	**3.168**	**.000**
Communica-tion	S1	S2	82.502	40.725	.116
		S3	92.714	48.306	.143
	S2	S3	10.212	47.905	.975
Practice	**S1**	**S2**	**-360.859***	**34.129**	**.000**
		S3	**-811.988***	**40.482**	**.000**
	S2	**S3**	**-451.129***	**40.146**	**.000**
Feedback	**S1**	S2	-7.955	4.842	.237
		S3	**-41.167***	**5.743**	**.000**
	S2	**S3**	**-33.212***	**5.696**	**.000**

Sample size: 56 Significance level: 0.10

Table 2-1-5. Tukey HSD test result for mean comparisons of affordance perception (survey data)

Affordance Perception	(I) Cluster	(J) Cluster	Mean Difference (I-J)	Std. Error	Sig.
Content Access	S1	S2	-.00048	.23964	1.00
		S3	-.43964	.28425	.278
	S2	S3	-.43917	.28189	.273
Submission	**S1**	S2	.06277	.22351	.957
		S3	**-.56238***	**.26512**	**.096**
	S2	**S3**	**-.61515***	**.26292**	**.059**
Communic-ation	S1	S2	.57115	.35760	.256
		S3	-.39810	.42417	.619
	S2	**S3**	**-.96924***	**.42065**	**.064**
Practice	S1	S2	.48225	.27392	.193
		S3	-.59048	.32492	.174
	S2	**S3**	**-1.07273***	**.32222**	**.005**
Feedback	S1	S2	.35498	.29134	.448
		S3	-.09048	.34557	.963
	S2	S3	-.44545	.34271	.402

APPENDIX 2-2. FACTOR ANALYSIS RESULTS FOR PILOT SURVEY ITEMS

Rotated component matrix[a]

Item ID	1	2	3	4	5
Aff1Q2.1_4				0.563	
Aff1Q2.5_1		0.41		0.48	
Aff1Q2.5_5				0.828	
Aff1Q2.5_7				0.756	
Aff1Q2.7_2		0.505			
Aff1Q2.7_4				0.527	
Aff2Q2.1_2					0.455
Aff2Q2.3_2			0.683		
Aff2Q2.3_5R					0.769
Aff2Q2.3_8			0.699		
Aff2Q2.5_9			0.643		
Aff3Q2.1_1	0.734				
Aff3Q2.1_3	0.764				
Aff3Q2.1_7	0.842				
Aff3Q2.1_8	0.85				
Aff3Q2.3_7R	0.615				
Aff3Q2.5_4	0.737				
Aff3Q2.7_1	0.693				
Aff4Q2.3_3R					0.679
Aff4Q2.3_4		0.713			
Aff4Q2.5_3		0.72			
Aff4Q2.5_8		0.693			
Aff4Q2.7_3	0.486	0.634			
Aff5Q2.1_5R					0.43
Aff5Q2.1_6		0.443	0.415		
Aff5Q2.3_1		0.597			
Aff5Q2.3_6			0.688		
Aff5Q2.5_2			0.708		
Aff5Q2.5_6		0.476	0.597		

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Loadings lower than 0.4 are suppressed

APPENDIX 2-3. SURVEY ITEMS AND NUMBER OF JUDGES WHO ASSIGNED EACH ITEM TO WHICH AFFORDANCE

Code	Item	Content Access	Submission	Communication	Practice	Feedback
CMU1	Moodle lets me interact with the teaching assistants.	0	0	10	0	0
CMU2	If I miss a class, I can use Moodle to contact my teacher about what I missed.	0	0	10	0	0
CMU3	Moodle lets me talk to the teacher.	0	0	10	0	0
CMU4	Moodle facilitates communication between the teacher and the students.	0	0	10	0	0
CMU5	Moodle is useful for keeping in contact with classmates.	0	0	10	0	0
CMU5-R	Moodle is not useful for keeping in contact with classmates.	0	0	10	0	0
CMU6	Moodle lets me interact with the teacher.	0	1	9	0	0
CMU7	Moodle lets me interact with others, including the teacher, the TA, and classmates.	0	0	10	0	0
CMU8	Moodle allows me to communicate with my group-mates.	0	0	10	0	0
CMU9	Moodle lets me send the teacher personal messages.	0	0	10	0	0

Code	Item	Content Access	Submission	Communication	Practice	Feedback
CMU10	Moodle lets me interact with my classmates.	0	0	10	0	0
CNT1	Moodle gives me access to the course materials, notes, and slides.	10	0	0	0	0
CNT2	Moodle lets me check the course outline.	10	0	0	0	0
CNT3	Moodle lets me know the dates when various information is needed for the course.	9	0	1	0	0
CNT4	Moodle lets me download the class slides.	10	0	0	0	0
CNT5	Moodle lets me find the teacher's notes.	9	0	1	0	0
CNT6	Moodle gives me an organized and structured layout of the course content and slides.	10	0	0	0	0
FDB1	Moodle gives me feedback on my grades all along the way.	0	0	0	0	10
FDB2	Moodle lets me know how I did in the last assignment.	0	0	0	0	10
FDB2-R	Moodle does not do a good job of letting me know how I did in the last assignment.	0	0	0	0	10
FDB3	Moodle lets me see my grades.	2	0	0	0	8
FDB4	Moodle tells me if I got the right answer, when I do practice quizzes.	1	0	0	7	2

Code	Item	Content Access	Submission	Communication	Practice	Feedback
FDB5	Moodle tells me my score in the quizzes that count for my grade.	0	0	0	0	10
FDB6	Moodle provides feedback on the assignments I submit.	0	0	0	0	10
PRC1	Moodle lets me do practice questions before each exam or quiz.	0	0	0	10	0
PRC2	Moodle supports me in practicing for upcoming exams.	1	0	0	9	0
PRC3	On Moodle, I can practice the types of questions I will see in tests and exams.	1	0	0	9	0
PRC4	Moodle lets me practice what I learn from reading the textbook.	0	0	0	10	0
PRC-R	Moodle does not do a good job of allowing me to do online practice questions.	1	0	0	9	0
SBM1	Moodle lets me provide my work to the teacher.	0	10	0	0	0
SBM2	Moodle lets the teacher receive my submissions.	0	10	0	0	0
SBM3	Moodle lets me revise and resubmit my work before the deadline if I submitted it early.	1	9	0	0	0
SBM4	Moodle lets me upload my assignments online, instead of handing in a physical copy.	0	10	0	0	0

Code	Item	Content Access	Submission	Communication	Practice	Feedback
SBM-R	Moodle does not do a good job in letting me submit my work for assignments.	0	10	0	0	0

- The highlighted item (FDB4) was removed due to inter-rater agreement of less than 80% among the judges.
- The items with codes that end in "-R" are the reverse coded items which were used as a quality check question. That is, they were used to catch and remove respondents who responded without carefully reading the questions. These items were not included in data analysis.
- CMU: Communication affordance
- CNT: Content Access affordance
- FDB: Feedback affordance
- PRC: Practice affordance
- SBM: Submission affordance

APPENDIX 2-4. SURVEY ITEMS FOR USER LEARNING STYLE: REDUCED INDEX OF LEARNING STYLE (ILS)

Dimension	Code	Item
Active	D1.Q3.1	I understand something better after I (a) try it out. (b) think it through.
	D1.Q3.13	In classes I have taken (a) I have usually gotten to know many of the students. (b) I have rarely gotten to know many of the students.
	D1.Q3.21	I prefer to study (a) in a study group. (b) alone.
	D1.Q3.25	I would rather first (a) try things out. (b) think about how I'm going to do it.
	D1.Q3.9	In a study group working on difficult material, I am more likely to (a) jump in and contribute ideas. (b) sit back and listen.
Sensing	D2.Q3.18	I prefer the idea of (a) certainty. (b) theory.
	D2.Q3.2	I would rather be considered (a) realistic. (b) innovative.
	D2.Q3.22	I am more likely to be considered (a) careful about the details of my work. (b) creative about how to do my work.
	D2.Q3.38	I prefer courses that emphasize (a) concrete material (facts, data). (b) abstract material (concepts, theories).
	D2.Q3.42	When I am doing long calculations, (a) I tend to repeat all my steps and check my work carefully. (b) I find checking my work tiresome and have to force myself to do it.
Visual	D3.Q3.11	In a book with lots of pictures and charts, I am likely to (a) look over the pictures and charts carefully. (b) focus on the written text.
	D3.Q3.31	When someone is showing me data, I prefer (a) charts or graphs.

Dimension	Code	Item
		(b) text summarizing the results.
	D3.Q3.35	When I meet people at a party, I am more likely to remember (a) what they looked like. (b) what they said about themselves.
	D3.Q3.39	For entertainment, I would rather (a) watch television. (b) read a book.
	D3.Q3.7	I prefer to get new information in (a) pictures, diagrams, graphs, or maps. (b) written directions or verbal information.
Sequential	D4.Q3.20	It is more important to me that an instructor (a) lay out the material in clear sequential steps. (b) give me an overall picture and relate the material to other subjects.
	D4.Q3.24	I learn (a) at a fairly regular pace. If I study hard, I'll "get it." (b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."
	D4.Q3.4	I tend to (a) understand details of a subject but may be fuzzy about its overall structure. (b) understand the overall structure but may be fuzzy about details.
	D4.Q3.44	When solving problems in a group, I would be more likely to (a) think of the steps in the solution process. (b) think of possible consequences or applications of the solution in a wide range of areas.
	D4.Q3.8	Once I understand (a) all the parts, I understand the whole thing. (b) the whole thing, I see how the parts fit.

APPENDIX 2-5. USER SURVEY

Survey on Student Experience with Moodle: Information and Consent to Participate in Research

You are being asked to participate in this survey as part of a research study on how students use Moodle in their learning experience. This study is being conducted by Mostafa Mesgari (mostafa.mesgari@concordia.ca, 514-562-4123), Doctoral Candidate, and Dr. Chitu Okoli (Chitu.Okoli@concordia.ca, 514-848-2424 x2985), Associate Professor, both in Business Technology Management at the John Molson School of Business of Concordia University. If you have any questions about this study, please contact either researcher.

What to expect

You will be provided with about 62 survey questions in which you will express your degree of agreement/ disagreement with the statements provided. It will take about 15-20 minutes to go through the questions. In addition, your instructor will provide the researchers access to some of the Moodle data including your actions and clicks on Moodle features throughout the course. This data will NOT include any of the content of your Moodle with your submissions, feedback, or grades. The Moodle data will be linked to your survey responses to better understand your use of Moodle.

Your name and identifying information will be kept STRICTLY CONFIDENTIAL. The researchers will not share any identifying information about you with anyone other than the research team. The researchers will not give your instructor your data including the survey responses.

Compensation

Every participant of this survey will get $5 gift as a little thank-you. To obtain this, you will need to have your student ID and visit the first researcher during his extended office hours listed at the end of this survey. If requested, you will receive a copy of the results of this research study.

Benefits and Risks

The benefit of your participation is to contribute information to JMSB and its community about your experience. This may assist in improving Moodle and the way instructors use it to enrich students' learning experience. There are no known risks associated with participating in the study.

Informed Consent and Privacy

In participating in this research study, I affirm the following:

- I am **voluntarily participating** in this research study.
- I understand that this study is CONFIDENTIAL, that is, **the researchers will know my identity, but will not disclose it to anyone**. Any information I submit that is analyzed, shared or published will be presented in a way that cannot reveal my identity.
- I understand that **none of my responses in the survey will be shared with my instructor** or with anyone else outside the research team in a way that could link the responses to me.
- I understand that by participating in this survey, **I agree to give the researchers access to the Moodle click-stream data** including my actions and clicks on Moodle features throughout this course. This will NOT include any of my Moodle content, submissions, feedbacks, or grades.
- I understand that **I may skip any question or task that I do not want to do** with no negative consequences.
- I understand that **I may stop participating at any time** with no negative consequences.
- I understand that **up to three weeks after this interview, I may request that my data be deleted from the study**, unless the data has already been aggregated and analyzed, in which case it would be impractical. I understand that if I ask for it, I will receive a copy of all the results of the study.
- I understand that **the results of this study will be distributed and published.** I understand that once the results are distributed, it will be infeasible to retract any prior permission I might have given.

By signing below, I acknowledge that I have read and understood the above information. I am aware that I can discontinue my participation in the study at any time.

Full Name (REQUIRED) _____

Signature _____ Date _____

If you have questions about the scientific or scholarly aspects of this research, please contact the researcher. His contact information is on top of the page. You may also contact his faculty supervisor.

If you have concerns about ethical issues in this research, please contact the Manager, Research Ethics, Concordia University, 514.848.2424 ex. 7481 or oor.ethics@concordia.ca.

Please indicate the degree of your agreement/disagreement with the following statements by circling the related number in each row.

Please **consider the Moodle site for this course** when you answer the questions.

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
Moodle lets me interact with the teaching assistants.	1	2	3	4	5	6	7
If I miss a class, I can use Moodle to contact my teacher about what I missed.	1	2	3	4	5	6	7
Moodle does not do a good job of letting me know how I did in the last assignment.	1	2	3	4	5	6	7
Moodle gives me feedback on my grades all along the way.	1	2	3	4	5	6	7
Moodle lets me talk to the teacher.	1	2	3	4	5	6	7
Moodle facilitates communication between the teacher and the students.	1	2	3	4	5	6	7
Moodle lets me do practice questions before each exam or quiz.	1	2	3	4	5	6	7
Moodle is useful for keeping in contact with classmates.	1	2	3	4	5	6	7
Moodle gives me access to the course materials, notes, and slides.	1	2	3	4	5	6	7
If you read this question, choose the option number four.	1	2	3	4	5	6	7
Moodle lets me provide my work to the teacher.	1	2	3	4	5	6	7
Moodle does not do a good job of allowing me to do online practice questions.	1	2	3	4	5	6	7

Comments: Please provide any comment you may have about the above questions.

Please indicate the degree of your agreement/disagreement with the following statements by circling the related number in each row.

Please **consider the Moodle site for this course** when you answer the questions.

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
Moodle lets me know how I did in the last assignment.	1	2	3	4	5	6	7
Moodle lets me interact with the teacher.	1	2	3	4	5	6	7
Moodle is not useful for keeping in contact with classmates.	1	2	3	4	5	6	7
Moodle lets me see my grades.	1	2	3	4	5	6	7
Moodle lets the teacher receive my submissions.	1	2	3	4	5	6	7
Moodle tells me if I got the right answer, when I do practice quizzes.	1	2	3	4	5	6	7
Moodle lets me check the course outline.	1	2	3	4	5	6	7
Moodle supports me in practicing for upcoming exams.	1	2	3	4	5	6	7
Moodle lets me interact with others, including the teacher, the TA, and classmates.	1	2	3	4	5	6	7
Moodle lets me revise and resubmit my work before the deadline if I submitted it early.	1	2	3	4	5	6	7
Moodle allows me to communicate with my group-mates.	1	2	3	4	5	6	7

Comments: Please provide any comment you may have about the above questions

Please indicate the degree of your agreement/disagreement with the following statements by circling the related number in each row.

Please **consider the Moodle site for this course** when you answer the questions.

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
Moodle tells me my score in the quizzes that count for my grade.	1	2	3	4	5	6	7
Moodle lets me send the teacher personal messages.	1	2	3	4	5	6	7
Moodle lets me know the dates when various information is needed for the course.	1	2	3	4	5	6	7
Moodle lets me download the class slides.	1	2	3	4	5	6	7
Moodle lets me upload my assignments online, instead of handing in a physical copy.	1	2	3	4	5	6	7
On Moodle, I can practice the types of questions I will see in tests and exams.	1	2	3	4	5	6	7
Moodle does not do a good job in letting me submit my work for assignments.	1	2	3	4	5	6	7
Moodle lets me interact with my classmates.	1	2	3	4	5	6	7
Moodle lets me practice what I learn from reading the textbook.	1	2	3	4	5	6	7
Moodle lets me find the teacher's notes.	1	2	3	4	5	6	7
Moodle provides feedback on the assignments I submit.	1	2	3	4	5	6	7
Moodle gives me an organized and structured layout of the course content and slides.	1	2	3	4	5	6	7

Comments: Please provide any comment you may have about the above questions

Learning Style Questions

Here are some questions about your learning style. For each of the questions in this section of the survey select ONE of the two options to indicate your answer. **If both options seem to apply to you, circle the one option that applies more frequently**.

It is VERY IMPORTANT that you spend enough time to consider each question and make sure you circle the one option that applies to you most frequently.

I would rather be considered
(a) realistic.
(b) innovative.

In a book with lots of pictures and charts, I am likely to
(a) look over the pictures and charts carefully.
(b) focus on the written text.

It is more important to me that an instructor
(a) lay out the material in clear sequential steps.
(b) give me an overall picture and relate the material to other subjects.

I prefer courses that emphasize
(a) concrete material (facts, data).
(b) abstract material (concepts, theories).

Once I understand
(a) all the parts, I understand the whole thing.
(b) the whole thing, I see how the parts fit.

I prefer to study
(a) in a study group.
(b) alone.

I understand something better after I
(a) try it out.
(b) think it through.

I learn
(a) at a fairly regular pace. If I study hard, I'll "get it."
(b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."

When I am doing long calculations,
(a) I tend to repeat all my steps and check my work carefully.
(b) I find checking my work tiresome and have to force myself to do it.

When solving problems in a group, I would be more likely to
(a) think of the steps in the solution process.
(b) think of possible consequences or applications of the solution in a wide range of areas.

It is VERY IMPORTANT that you spend enough time to consider each question and make sure you circle the one option that applies to you most frequently.

I would rather first
(a) try things out.
(b) think about how I'm going to do it.

I am more likely to be considered
(a) careful about the details of my work.
(b) creative about how to do my work.

When someone is showing me data, I prefer
(a) charts or graphs.
(b) text summarizing the results.

In classes I have taken
(a) I have usually gotten to know many of the students.
(b) I have rarely gotten to know many of the students.

In a study group working on difficult material, I am more likely to
(a) jump in and contribute ideas.
(b) sit back and listen.

I tend to
(a) understand details of a subject but may be fuzzy about its overall structure.
(b) understand the overall structure but may be fuzzy about details.

For entertainment, I would rather
(a) watch television.
(b) read a book.

If you are reading this question, choose the shortest sentence below
(a) I think this is a short sentence
(b) this is very long sentence compared to the other option available for this question.

When I meet people at a party, I am more likely to remember
(a) what they looked like.
(b) what they said about themselves.

I prefer to get new information in
(a) pictures, diagrams, graphs, or maps.
(b) written directions or verbal information.

I prefer the idea of
(a) certainty.
(b) theory.

Demographic Information

Age range: ☐ 20 & under ☐ 21 to 25 ☐ 26 to 35 ☐ 36 to 45 ☐ 46 & above

Gender: ☐ Male ☐ Female ☐ Other

How many credits does your program require? ☐ 120 ☐ 90 ☐ other

By the end of this semester, how many credits will you have completed?

☐ 0 to 30 ☐ 31 to 60 ☐ 61 to 90 ☐ 91 to 120 ☐ 121 & more

What is you major?

☐ Administration (BAdmin) ☐Business Technology Management ☐ Marketing

☐ Economics ☐ Finance ☐ Management ☐ Human Resource Management

☐ International Business ☐ Supply Chain Operations Management ☐ Others

How many courses including this present semester have you used Moodle for?

☐ 1 ☐ 2 ☐ 3 to 5 ☐ 6 & more

Thank you for your participation.

To collect the $5 gift for this study, you may visit the principal researcher, Mostafa Mesgari, in his office hours as per the following schedule. Please DO NOT FORGET to bring your student ID with you, so your participation can be identified. Please do not hesitate to email him at mostafa.mesgari@concordia.ca if you have any question about this study and your participation.

Office Hours:

APPENDIX 2-6. RESULTS OF THE CARD SORTING FOR ACTIONS INTO AFFORDANCES

Affordance	Action name	Action Definition
Content Access	assign_view (before submission)	Visiting the main page of an assignment (the one with instructions and status of your submission), before submitting the assignment
	assign_view all	Visiting the page for all assignments
	book_view	Visiting a book page
	book_view all	Visiting the page for all books
	book_view chapter	Visiting chapters of a book
	course_view	Visiting the main page of the course website
	data_view	Visiting any of the pages of a Moodle database
	folder_view	Visiting a folder
	folder_view all	Visiting the page for all folders
	imscp_view all	Visiting the page that lists all multimedia content
	label_view all	Visiting the page that list titles of all course content
	lti_launch	Opening an external tool (e.g. electronic textbook)
	lti_view all	Visiting the page that lists all external tools (e.g. electronic textbook)
	page_view	Visiting a dedicated page with specific information (e.g. cases, activity, etc.)
	page_view all	Visiting the page that lists all dedicated pages with specific information (e.g. cases, activity, etc.)
	quiz_view (for graded quizzes)	Visiting the main page of a graded quiz (the one with instructions about the quiz)
	resource_view	Accessing a file on Moodle (e.g. slides, documents, etc.)
	resource_view all	Visiting the page that lists all downloadable files (e.g. slides, documents, etc.)
	url_view	Visiting a website link provided on Moodle
	url_view all	Visiting the page that list all website links provided on Moodle
Submission	assign_submission statement accepted	Accepting the submission statement ("This assignment is my own work, except where I have acknowledged the use of the works of other people.")
	assign_submit	Submitting an assignment
	assign_view submit assignment form	Visiting the page to upload files for your assignment
	data_add	Posting to a Moodle database
	data_update	Updating/changing your post on a Moodle database

	quiz_attempt (for graded quizzes)	Starting to do a graded quiz
	quiz_close attempt (for graded quizzes)	Submitting your answers to a graded quiz once you are finished
	quiz_continue attempt (for graded quizzes)	Continuing to the next question of a graded quiz
Communication	discussion_mark read	Marking a forum discussion as read
	forum_add discussion	Posting a new discussion to a forum
	forum_add post	Replying to an existing discussion on a forum
	forum_delete discussion	Deleting your discussion on a forum
	forum_delete post	Deleting your post on a forum
	forum_subscribe	Subscribing to a forum
	forum_unsubscribe	Unsubscribing from a forum
	forum_update post	Updating/changing your post on a forum
	forum_view discussion	Visiting one of the discussions on a forum
	forum_view forum	Visiting the first page of a forum
Practice	quiz_attempt (for practice quizzes)	Starting to do a practice quiz
	quiz_close attempt (for practice quizzes)	Submitting your answers to a practice quiz once you are finished
	quiz_continue attempt (for practice quizzes)	Continuing to the next question of a practice quiz
Feedback	assign_view (after submission)	Visiting the main page of an assignment (the one with instructions and status of your submission), after submitting the assignment
	quiz_review (for practice quizzes)	Reviewing a practice quiz and your answers after you are finished
	quiz_review (for graded quizzes)	Reviewing a graded quiz and your answers after you are finished
	quiz_view all	Visiting the page that lists all quizzes (whether practice or graded) with your scores, if available
	quiz_view summary (for practice quizzes)	Checking the summary of your answers to a practice quiz
	quiz_view summary (for graded quizzes)	Checking the summary of your answers to a graded quiz
Not Agreed	course_recent	Visiting the page that lists your recent activities in Moodle
	forum_search	Searching within the forums
	forum_view forums	Visiting the page that lists all forums
	quiz_view (for practice quizzes)	Visiting the main page of a practice quiz (the one with instructions about the quiz)
	user_view	Visiting someone's user profile
	user_view all	Viewing the list of all participants in the Moodle course

APPENDIX 2-7. RESULTS OF CLUSTER ANALYSIS BASED ON ALL FIVE AFFORDANCES

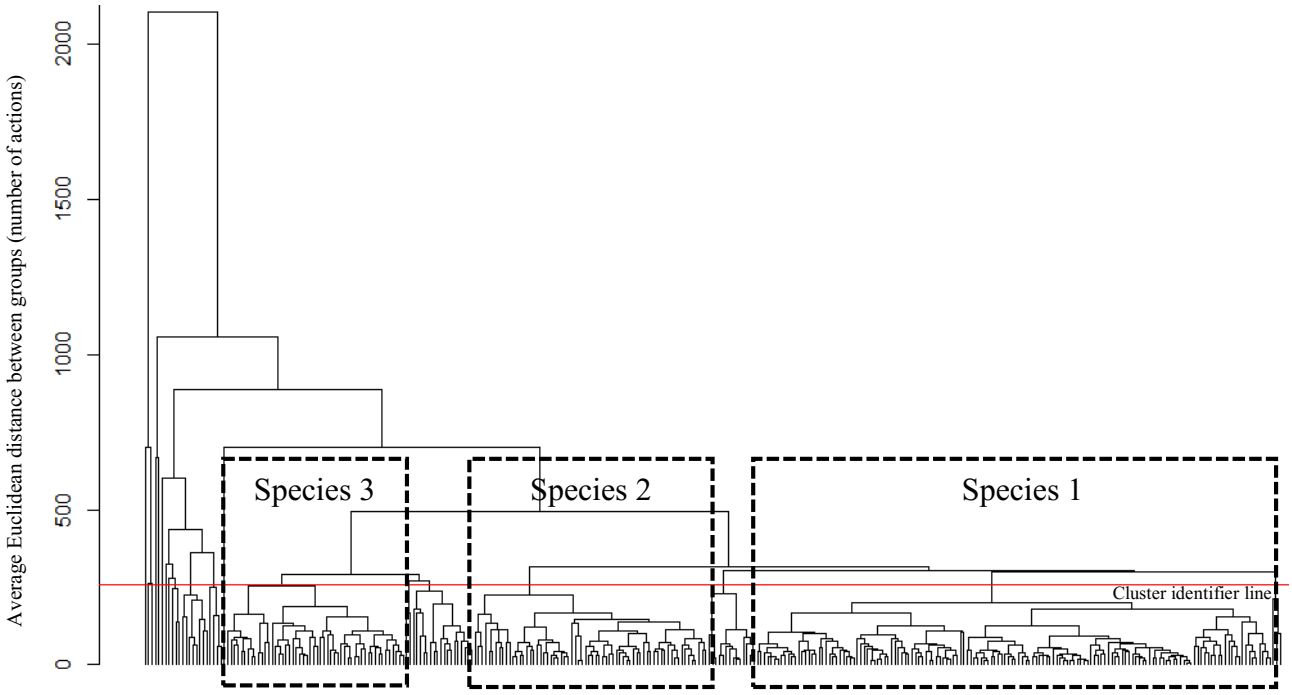

Figure 2-7-1. Dendrogram from Hierarchical Cluster Analysis

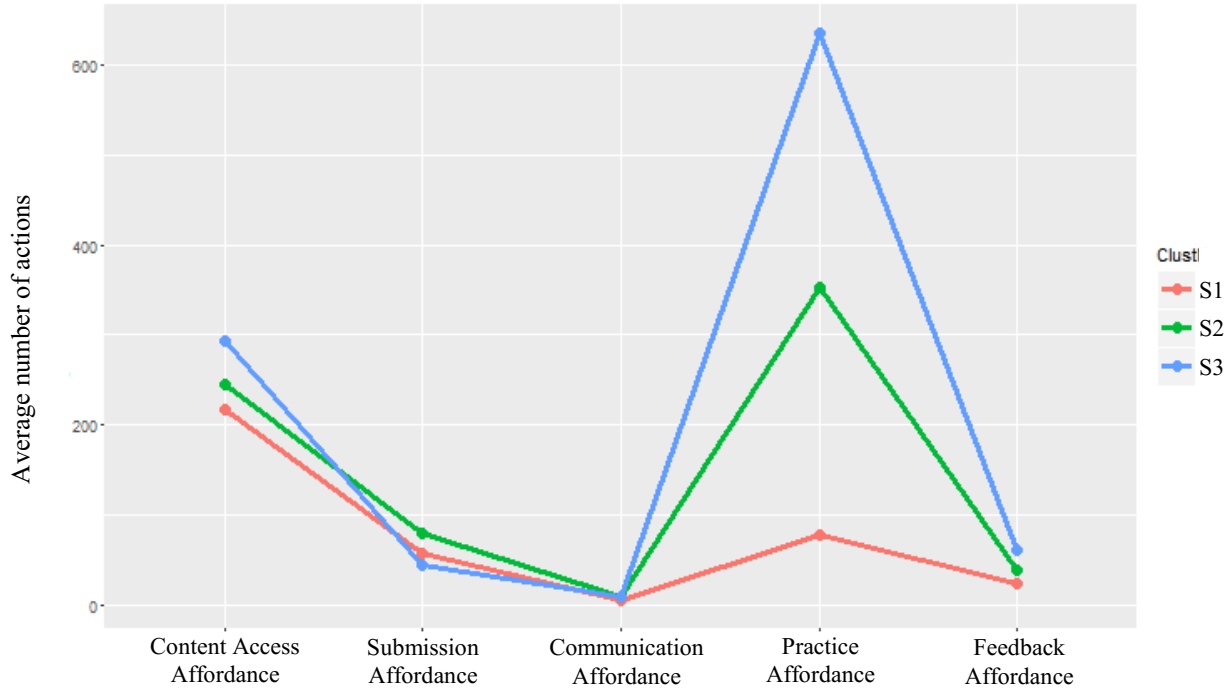

Figure 2-7-2. Average affordance actualization (log data)

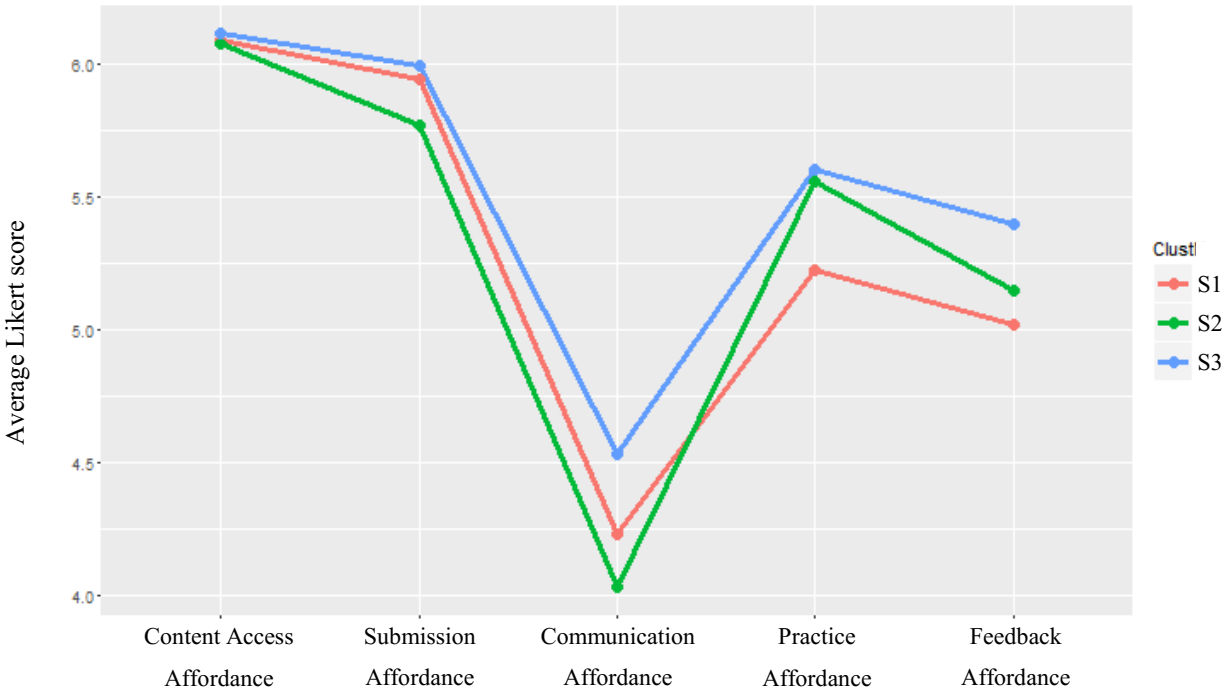

Figure 2-7-3. Average affordance perception (survey responses)

Table 2-7-1. ANOVA results for mean difference in affordance actualization (log data)

Affordance Actualization	Mean (S1)	Mean (S2)	Mean (S3)	F	P-value
Content Access	217.8	244.9	293.2	16.33	.000
Submission	57.7	79	44.8	6.23	.000
Communication	6.3	8.3	9.1	1.18	.309
Practice	77.2	353.5	635.9	1009.00	.000
Feedback	24.4	39.6	61.7	46.34	.000

Sample size: 331

Table 2-7-2. Tukey HSD test result for mean comparisons of affordance actualization (log data)

Affordance Actualization	Cluster (I)	Cluster (J)	Mean Difference (I-J)	Std. Error	P-value
Content Access	**S1**	**S2**	**-27.132**	**12.073**	**.065**
		S3	**-75.431**	**13.290**	**.000**
	S2	**S3**	**-48.300**	**15.213**	**.005**
Submission	**S1**	**S2**	**-21.239**	**7.989**	**.023**
		S3	12.958	8.794	.305
	S2	**S3**	**34.197**	**10.066**	**.002**
Communication	S1	S2	-2.005	1.839	.521
		S3	-2.724	2.025	.371
	S2	S3	-.719	2.318	.948
Practice	**S1**	**S2**	**-276.364**	**11.712**	**.000**
		S3	**-558.705**	**12.892**	**.000**
	S2	**S3**	**-282.340**	**14.758**	**.000**
Feedback	**S1**	**S2**	**-15.179**	**3.568**	**.000**
		S3	**-37.258**	**3.927**	**.000**
	S2	**S3**	**-22.079**	**4.496**	**.000**

Sample size: 331

APPENDIX 2-8. CONTINGENCY TABLE FOR MEMBERS OF THE THREE SPECIES ACROSS SECTIONS

			Species			Total
			S1	S2	S3	
Section Code	F5150C	Count	7a	16b	1a, b	24
		Expected Count	12.0	9.7	2.3	24.0
		% within Section	29.2%	66.7%	4.2%	100.0%
		% within Species	4.5%	12.8%	3.3%	7.7%
		Std. Residual	-1.4	2.0	-.9	
	F5150J	Count	6a	3a	0a	9
		Expected Count	4.5	3.6	.9	9.0
		% within Section	66.7%	33.3%	0.0%	100.0%
		% within Species	3.9%	2.4%	0.0%	2.9%
		Std. Residual	.7	-.3	-.9	
	F515AA	Count	7a	2a	0a	9
		Expected Count	4.5	3.6	.9	9.0
		% within Section	77.8%	22.2%	0.0%	100.0%
		% within Species	4.5%	1.6%	0.0%	2.9%
		Std. Residual	1.2	-.9	-.9	
	F515BB	Count	4a	5a	0a	9
		Expected Count	4.5	3.6	.9	9.0
		% within Section	44.4%	55.6%	0.0%	100.0%
		% within Species	2.6%	4.0%	0.0%	2.9%
		Std. Residual	-.2	.7	-.9	
	F5250A	Count	10a	6a	0a	16
		Expected Count	8.0	6.5	1.5	16.0
		% within Section	62.5%	37.5%	0.0%	100.0%
		% within Species	6.5%	4.8%	0.0%	5.2%
		Std. Residual	.7	-.2	-1.2	
	F5250B	Count	17a	12a	7a	36
		Expected Count	18.0	14.5	3.5	36.0
		% within Section	47.2%	33.3%	19.4%	100.0%
		% within Species	11.0%	9.6%	23.3%	11.6%

		Std. Residual	-.2	-.7	1.9	
	F5250C	Count	13a	14a	3a	30
		Expected Count	15.0	12.1	2.9	30.0
		% within Section	43.3%	46.7%	10.0%	100.0%
		% within Species	8.4%	11.2%	10.0%	9.7%
		Std. Residual	-.5	.5	.1	
	F5250D	Count	14a	13a	2a	29
		Expected Count	14.5	11.7	2.8	29.0
		% within Section	48.3%	44.8%	6.9%	100.0%
		% within Species	9.0%	10.4%	6.7%	9.4%
		Std. Residual	-.1	.4	-.5	
	F5250E	Count	5a	3a	1a	9
		Expected Count	4.5	3.6	.9	9.0
		% within Section	55.6%	33.3%	11.1%	100.0%
		% within Species	3.2%	2.4%	3.3%	2.9%
		Std. Residual	.2	-.3	.1	
	F525BB	Count	7a	8a	1a	16
		Expected Count	8.0	6.5	1.5	16.0
		% within Section	43.8%	50.0%	6.2%	100.0%
		% within Species	4.5%	6.4%	3.3%	5.2%
		Std. Residual	-.4	.6	-.4	
	F5260A	Count	7a	7a	2a	16
		Expected Count	8.0	6.5	1.5	16.0
		% within Section	43.8%	43.8%	12.5%	100.0%
		% within Species	4.5%	5.6%	6.7%	5.2%
		Std. Residual	-.4	.2	.4	
	F5260B	Count	19a	13a	4a	36
		Expected Count	18.0	14.5	3.5	36.0
		% within Section	52.8%	36.1%	11.1%	100.0%
		% within Species	12.3%	10.4%	13.3%	11.6%
		Std. Residual	.2	-.4	.3	
	F5260C	Count	8a	1a	0a	9
		Expected Count	4.5	3.6	.9	9.0
		% within Section	88.9%	11.1%	0.0%	100.0%
		% within Species	5.2%	0.8%	0.0%	2.9%
		Std. Residual	1.6	-1.4	-.9	

	F526AA	Count	22a	21a	9a	52
		Expected Count	26.0	21.0	5.0	52.0
		% within Section	42.3%	40.4%	17.3%	100.0%
		% within Species	14.2%	16.8%	30.0%	16.8%
		Std. Residual	-.8	.0	1.8	
	F526BB	Count	9a	1a	0a	10
		Expected Count	5.0	4.0	1.0	10.0
		% within Section	90.0%	10.0%	0.0%	100.0%
		% within Species	5.8%	0.8%	0.0%	3.2%
		Std. Residual	1.8	-1.5	-1.0	
Total		Count	155	125	30	310
		Expected Count	155.0	125.0	30.0	310.0
		% within Section	50.0%	40.3%	9.7%	100.0%
		% within Species	100.0%	100.0%	100.0%	100.0%

Each “a” or “b” letter after the count numbers denotes a subset of Species categories whose column proportions do not differ significantly from each other at the .05 level.

APPENDIX 2-9. CONTINGENCY TABLE FOR MEMBERS OF THE THREE SPECIES ACROSS INSTRUCTORS

			Species			Total
			S1	S2	S3	
Instructor Code	INS1	Count	12a	11a	2a	25
		Expected Count	12.5	10.1	2.4	25.0
		% within Instructor	48.0%	44.0%	8.0%	100.0%
		% within Species	7.7%	8.8%	6.7%	8.1%
		Std. Residual	-.1	.3	-.3	
	INS2	Count	44a	39a	12a	95
		Expected Count	47.5	38.3	9.2	95.0
		% within Instructor	46.3%	41.1%	12.6%	100.0%
		% within Species	28.4%	31.2%	40.0%	30.6%
		Std. Residual	-.5	.1	.9	
	INS3	Count	8a	1a	0a	9
		Expected Count	4.5	3.6	.9	9.0
		% within Instructor	88.9%	11.1%	0.0%	100.0%
		% within Species	5.2%	0.8%	0.0%	2.9%
		Std. Residual	1.6	-1.4	-.9	
	INS4	Count	7a	7a	2a	16
		Expected Count	8.0	6.5	1.5	16.0
		% within Instructor	43.8%	43.8%	12.5%	100.0%
		% within Species	4.5%	5.6%	6.7%	5.2%
		Std. Residual	-.4	.2	.4	
	INS5	Count	10a	6a	0a	16
		Expected Count	8.0	6.5	1.5	16.0
		% within Instructor	62.5%	37.5%	0.0%	100.0%
		% within Species	6.5%	4.8%	0.0%	5.2%
		Std. Residual	.7	-.2	-1.2	
		Count	9a	1a	0a	10
		Expected Count	5.0	4.0	1.0	10.0
		% within Instructor	90.0%	10.0%	0.0%	100.0%
		% within Species	5.8%	0.8%	0.0%	3.2%

		Std. Residual	1.8	-1.5	-1.0	
	INS6	Count	19a	13a	4a	36
		Expected Count	18.0	14.5	3.5	36.0
		% within Instructor	52.8%	36.1%	11.1%	100.0%
		% within Species	12.3%	10.4%	13.3%	11.6%
		Std. Residual	.2	-.4	.3	
	INS7	Count	22a	21a	9a	52
		Expected Count	26.0	21.0	5.0	52.0
		% within Instructor	42.3%	40.4%	17.3%	100.0%
		% within Species	14.2%	16.8%	30.0%	16.8%
		Std. Residual	-.8	.0	1.8	
		Count	24a	26a	1a	51
		Expected Count	25.5	20.6	4.9	51.0
		% within Instructor	47.1%	51.0%	2.0%	100.0%
		% within Species	15.5%	20.8%	3.3%	16.5%
		Std. Residual	-.3	1.2	-1.8	
Total		Count	155	125	30	310
		Expected Count	155.0	125.0	30.0	310.0
		% within Instructor	50.0%	40.3%	9.7%	100.0%
		% within Species	100.0%	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Species categories whose column proportions do not differ significantly from each other at the .05 level.

APPENDIX 2-10. CONTINGENCY TABLE FOR GENDER, EXPERIENCE, DEPARTMENT, AND AGE ACROSS THE THREE SPECIES

Table 2-10-1. Contingency table for gender across species

			Gender		Total
			Male	Female	
Species	S1	Count	81a	74a	155
		Expected Count	73.5	81.5	155.0
		% within Species	52.3%	47.7%	100.0%
		% within Gender	55.5%	45.7%	50.3%
		Std. Residual	.9	-.8	
	S2	Count	52a	71a	123
		Expected Count	58.3	64.7	123.0
		% within Species	42.3%	57.7%	100.0%
		% within Gender	35.6%	43.8%	39.9%
		Std. Residual	-.8	.8	
	S3	Count	13a	17a	30
		Expected Count	14.2	15.8	30.0
		% within Species	43.3%	56.7%	100.0%
		% within Gender	8.9%	10.5%	9.7%
		Std. Residual	-.3	.3	
Total		Count	146	162	308
		Expected Count	146.0	162.0	308.0
		% within Species	47.4%	52.6%	100.0%
		% within Gender	100.0%	100.0%	100.0%

Each subscript letter denotes a subset of Gender categories whose column proportions do not differ significantly from each other at the .05 level.

Total count is 308 because 2 users were not analyzed because their gender values were missing.

Table 2-10-2. Contingency table for Moodle experience across species

			No. of courses enrolled on Moodle			Total
			1-2	3-5	≥6	
Species	S1	Count	11	67	77	155
		Expected Count	8.0	78.0	69.0	155.0
		% within Species	7.1%	43.2%	49.7%	100.0%
		% within Experience	68.8%	42.9%	55.8%	50.0%
		% of Total	3.5%	21.6%	24.8%	50.0%
		Std. Residual	1.1	-1.2	1.0	
	S2	Count	4	73	48	125
		Expected Count	6.5	62.9	55.6	125.0
		% within Species	3.2%	58.4%	38.4%	100.0%
		% within Experience	25.0%	46.8%	34.8%	40.3%
		% of Total	1.3%	23.5%	15.5%	40.3%
		Std. Residual	-1.0	1.3	-1.0	
	S3	Count	1	16	13	30
		Expected Count	1.5	15.1	13.4	30.0
		% within Species	3.3%	53.3%	43.3%	100.0%
		% within Experience	6.2%	10.3%	9.4%	9.7%
		% of Total	0.3%	5.2%	4.2%	9.7%
		Std. Residual	-.4	.2	-.1	
Total		Count	16	156	138	310
		Expected Count	16.0	156.0	138.0	310.0
		% within Species	5.2%	50.3%	44.5%	100.0%
		% within Experience	100.0%	100.0%	100.0%	100.0%
		% of Total	5.2%	50.3%	44.5%	100.0%

Table 2-10-3. Contingency table for the users' department across species

			Department						Total
			Accountancy	Supply Chain and BTM	Marketing	Economics	Finance	Management	
Species	S1	Count	46	12	13	12	30	35	148
		Expected Count	44.7	15.2	13.3	11.8	26.6	36.4	148.0
		% within Species	31.1 %	8.1%	8.8%	8.1%	20.3 %	23.6 %	100.0 %
		% within Department	50.5 %	38.7 %	48.1 %	50.0 %	55.6 %	47.3 %	49.2 %
		% of Total	15.3 %	4.0%	4.3%	4.0%	10.0 %	11.6 %	49.2 %
		Std. Residual	.2	-.8	-.1	.1	.7	-.2	
	S2	Count	39	14	12	11	16	31	123
		Expected Count	37.2	12.7	11.0	9.8	22.1	30.2	123.0
		% within Species	31.7 %	11.4 %	9.8%	8.9%	13.0 %	25.2 %	100.0 %
		% within Department	42.9 %	45.2 %	44.4 %	45.8 %	29.6 %	41.9 %	40.9 %
		% of Total	13.0 %	4.7%	4.0%	3.7%	5.3%	10.3 %	40.9 %
		Std. Residual	.3	.4	.3	.4	-1.3	.1	
	S3	Count	6	5	2	1	8	8	30
		Expected Count	9.1	3.1	2.7	2.4	5.4	7.4	30.0
		% within Species	20.0 %	16.7 %	6.7%	3.3%	26.7 %	26.7 %	100.0 %
		% within Department	6.6%	16.1 %	7.4%	4.2%	14.8 %	10.8 %	10.0 %
		% of Total	2.0%	1.7%	0.7%	0.3%	2.7%	2.7%	10.0 %
		Std. Residual	-1.0	1.1	-.4	-.9	1.1	.2	
Total		Count	91	31	27	24	54	74	301
		Expected Count	91.0	31.0	27.0	24.0	54.0	74.0	301.0

	% within Species	30.2 %	10.3 %	9.0%	8.0%	17.9 %	24.6 %	100.0 %
	% within Department	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
	% of Total	30.2 %	10.3 %	9.0%	8.0%	17.9 %	24.6 %	100.0 %

Table 2-10-4. Contingency table for users' age across species

			Age			Total
			20 & less	**21-25**	**26 & more**	
Species	S1	Count	44	99	12	155
		Expected Count	54.0	85.0	16.0	155.0
		% within Species	28.4%	63.9%	7.7%	100.0%
		% within Age	40.7%	58.2%	37.5%	50.0%
		% of Total	14.2%	31.9%	3.9%	50.0%
		Std. Residual	-1.4	1.5	-1.0	
	S2	Count	51	57	17	125
		Expected Count	43.5	68.5	12.9	125.0
		% within Species	40.8%	45.6%	13.6%	100.0%
		% within Age	47.2%	33.5%	53.1%	40.3%
		% of Total	16.5%	18.4%	5.5%	40.3%
		Std. Residual	1.1	-1.4	1.1	
	S3	Count	13	14	3	30
		Expected Count	10.5	16.5	3.1	30.0
		% within Species	43.3%	46.7%	10.0%	100.0%
		% within Age	12.0%	8.2%	9.4%	9.7%
		% of Total	4.2%	4.5%	1.0%	9.7%
		Std. Residual	.8	-.6	-.1	
Total		Count	108	170	32	310
		Expected Count	108.0	170.0	32.0	310.0
		% within Species	34.8%	54.8%	10.3%	100.0%
		% within Age	100.0%	100.0%	100.0%	100.0%
		% of Total	34.8%	54.8%	10.3%	100.0%

APPENDIX 2-11. PROCESS OUTPUT FOR ANALYSIS OF THE MEDIATED EFFECT OF GENDER

```
Run MATRIX procedure:

************* PROCESS Procedure for SPSS Beta Release 140712 *************

        Written by Andrew F. Hayes, Ph.D.   http://www.afhayes.com

**************************************************************************
Model = 4
    Y = ClustNo.
    X = Gender
    M = VIS

Sample size
        308

**************************************************************************
Outcome: VIS

Model Summary
          R       R-sq          F        df1        df2          p
      .1696      .0288     9.0659     1.0000   306.0000      .0028

Model
              coeff         se          t          p       LLCI       ULCI
constant     1.5864      .2136     7.4270      .0000     1.2340     1.9388
Gender        .9341      .3102     3.0110      .0028      .4223     1.4460

**************************************************************************
Outcome: ClustNo.

Model Summary
          R       R-sq          F        df1        df2          p
      .1644      .0270     4.2371     2.0000   305.0000      .0153

Model
              coeff         se          t          p       LLCI       ULCI
constant     1.7023      .0559    30.4727      .0000     1.6101     1.7944
VIS          -.0341      .0138    -2.4796      .0137     -.0568     -.0114
Gender       -.0820      .0758    -1.0824      .2799     -.2071      .0430

************************ TOTAL EFFECT MODEL ****************************
Outcome: ClustNo.
```

```
Model Summary
          R       R-sq          F        df1        df2          p
      .0861      .0074     2.2875     1.0000   306.0000      .1315

Model
              coeff         se          t          p       LLCI       ULCI
constant     1.6481      .0519    31.7865      .0000     1.5626     1.7337
Gender       -.1139      .0753    -1.5124      .1315     -.2382      .0103

***************** TOTAL, DIRECT, AND INDIRECT EFFECTS ********************

Total effect of X on Y
     Effect         SE          t          p       LLCI       ULCI
     -.1139      .0753    -1.5124      .1315     -.2382      .0103

Direct effect of X on Y
     Effect         SE          t          p       LLCI       ULCI
     -.0820      .0758    -1.0824      .2799     -.2071      .0430

Indirect effect of X on Y
        Effect    Boot SE   BootLLCI   BootULCI
VIS     -.0319      .0178     -.0703     -.0092

Partially standardized indirect effect of X on Y
        Effect    Boot SE   BootLLCI   BootULCI
VIS     -.0482      .0270     -.1065     -.0142

Completely standardized indirect effect of X on Y
        Effect    Boot SE   BootLLCI   BootULCI
VIS     -.0241      .0135     -.0532     -.0071

Ratio of indirect to total effect of X on Y
        Effect    Boot SE   BootLLCI   BootULCI
VIS      .2798 4.604E+010      .0418     2.8860

Ratio of indirect to direct effect of X on Y
        Effect    Boot SE   BootLLCI   BootULCI
VIS      .3886    68.3201      .0616    16.8008

R-squared mediation effect size (R-sq_med)
        Effect    Boot SE   BootLLCI   BootULCI
VIS      .0037      .0038      .0001      .0146

Preacher and Kelley (2011) Kappa-squared
        Effect    Boot SE   BootLLCI   BootULCI
VIS      .0239      .0132      .0070      .0524

Normal theory tests for indirect effect
```

```
     Effect         se          Z          p
     -.0319      .0172    -1.8541      .0637

******************** ANALYSIS NOTES AND WARNINGS ************************
Number of bootstrap samples for bias corrected bootstrap confidence
intervals:
     5000
Level of confidence for all confidence intervals in output:
    90.00
NOTE: Some cases were deleted due to missing data.  The number of such cases
was:
  23
NOTE: Sample size is 308 because 2 users were not analyzed because their
gender values were missing.
------ END MATRIX -----
```

APPENDIX 3-1. PILOT STUDY

Extract from: Mesgari, Mostafa, Chitu Okoli and Ana Ortiz de Guinea (2015). Affordance-based User Personas: A Mixed-Method Approach to Persona Development. Proceedings of the 21st Americas Conference on Information Systems. *Puerto Rico. August 13-15, 2015.*

We conducted 5 interviews with experienced student users of Moodle to identify the major affordances provided by Moodle to the student community. Next, we conducted two rounds of the card sorting technique to assign user actions to the identified affordances. Then we used cluster analysis to analyze the student log data to find out the patterns in student behaviour and how they actualize various Moodle affordances relative to each other. The identified clusters can form the basis for creating the user personas for the Moodle developer community.

Interviews: Identifying Affordances in Moodle

To recruit experienced users, we invited about 400 undergraduate students of a North American university by email to register for an interview session about their experiences with Moodle, if they had completed at least two courses that used Moodle. We offered a $10 compensation to participants for their time. 13 students registered to participate in the study by filling a form that explained the nature and extent of their experience. Five of their most experienced ones were contacted to schedule for an interview session. They were interviewed on two consecutive days in February 2015. Appendix 1 provides some demographic and Moodle experience information about the five interviewees. Interviews were audio recorded and took between 30 to 50 minutes each.

The semi-structured interviews followed an interview guide. We started with general questions about their studies, Internet experience, and experience with Moodle or any other learning platform. Then we asked them about how they liked or disliked Moodle, and other general questions to encourage them to talk about their experiences, possibilities, activities, and purposes on Moodle. We also asked them to describe their everyday experience on Moodle.

To analyze the data, we transcribed the recorded interviews and followed qualitative data analysis guidelines (Charmaz 2006) to openly code the data into every possible action, task, and

purpose the interviewees were describing. Next, we used axial coding to relate the open codes and group the related actions and behaviours into functional categories, and let meaningful affordances emerge. Special caution was given to the fact that affordances a) are functional and thus express students' explained purposes and goals; and b) cover the range of behaviours we captured in the interview data. After going through the qualitative coding and analysis process, five main Moodle affordances emerged. As the quotes of students (Appendix 2) demonstrate, the affordances took into consideration students' purposes and motives while using Moodle. The five affordances follow:

- **Content Access:** Action possibilities enabling the students to access any course content that they need; these possibilities give the students read-only access to the course-related material
- **Submission:** Action possibilities enabling the students to submit their work, answers, ideas, which might or might not receive subsequent feedback
- **Communication:** Action possibilities enabling the students to communicate and share their ideas, opinion, and questions with the teacher, teaching assistants or fellow classmates; or to acquire awareness of what the teacher, teaching assistants or classmates communicated or shared; both parties have the chance to express themselves and engage in two-way interaction
- **Practice:** Action possibilities enabling the students to practice what they have already learned about the course material
- **Feedback:** Action possibilities enabling the students to get feedback on their learning, participation, submitted work, or status or progress in the course

Card Sorting: Relating Affordances to Actions

Card sorting was employed to understand how user actions on Moodle actualize the five major affordances identified in the previous step. The list of actions were extracted from the log data of the 42 students using Moodle for a specific course. This course required an extensive use of Moodle and thus, covered a wide range of student actions possible. 35 different actions were identified from the dataset (Appendix 3).

We conducted two rounds of card sorting with 4 experienced student users (called "judges" in card sorting) in each round. In the first round, the judges were asked to sort any of the 35 identified user actions into one of the five identified affordance categories. One of the researchers met with each judge in person and explained the exercise with the categories and actions. Then, the judge went through actions on a specially-designed excel sheet and, considering their personal experience on Moodle, assigned each action to the most relevant affordance category that is actualized and fulfilled by that action. At the end, the researcher asked questions about the reasoning behind the judges' choices. This helped us understand users' intentions and purposes behind their actions and clarify the definition of the affordances we provided.

The first round of card sorting practice resulted in inter-rater reliability, Fleiss' kappa, of 0.721 demonstrating an acceptable level of agreement between the judges (see Table 3-1-1); a kappa higher than 0.65 can be considered an acceptable level of inter-rater agreement (Moore and Benbasat 1991). The first round of card sorting resulted in three changes to the actions and affordances, related to clarifying that the quizzes we referred to in our dataset were voluntary quizzes; whether the visit to the main page of an assignment was before or after the assignment due date; and clarifying our definition of the Communication affordance.

Table 3-1-1. Inter-rater reliability statistics for two rounds of card sorting

Round Number	Number of items (actions)	Number of Categories (Affordances)	Number of Raters	Kappa for Content Access Affordance	Kappa for Submission Affordance	Kappa for Communication	Kappa for Practice Affordance	Kappa for Feedback Affordance	**Overall Kappa for the round**	Standard Error	Lower Confidence Interval	Upper Confidence Interval
1	35	5	4	0.74	0.59	0.73	0.82	0.78	**0.72**	0.039	0.64	0.80
2	36	5	4	0.85	0.96	0.87	0.82	0.82	**0.87**	0.038	0.80	0.95

For the second round, the procedure of the first round was repeated with 4 different experienced student users and the revised set of actions and affordance definitions. Because an agreed upon list of affordances and actions was attained (see Table 3-1-1), no more rounds of card sorting were

needed. The content and results of both rounds of the card sorting procedure, and the list of actions that actualize each affordance are provided in the full report of the pilot study (Mesgari et al. 2015).

Cluster Analysis: Identifying Personas

To prepare the data for processing, we ran hierarchical clustering to look for singleton clusters; we found one and removed it from the dataset as an outlier. In order to retain the variation and the proportional importance of different variables, we chose not to standardize the data. Furthermore, the Pearson correlation measure of distance that we used, as explained later, makes it unnecessary to standardize the dataset.

SPSS version 22 was used to conduct hierarchical clustering which is appropriate clustering method for smaller samples. Our dataset includes more than 12,000 actions (user log records) conducted by 41 students (after outlier removal). The agglomerative hierarchical clustering procedure used in this study starts with one cluster for each data point and then computes the closest clusters and merges them into one cluster. This process of agglomeration continues until it gets to one general cluster including all data points. We employed a clustering method based on between-group linkages in which the average distance between each two members of every two clusters are computed, and the two groups with the smallest average distance are merged. Furthermore, we chose a distance measure of Pearson correlation because our goal is to create personas representing major user behaviours. What matters to us is the *pattern* rather than the *level* of affordance actualization, because we are interested in how users actualize affordances proportionally and in relation to other affordances. Personas would be more informative to a system design team when they are representative of how users use the system rather than how much they use it; this means focusing on the quality of use rather than its quantity. Hierarchical clustering based on Pearson correlation distance results in clusters each including students of highly correlated affordance actualization measures. In other words, students of each cluster supposedly will follow similar, correlated, manner in how they actualize various affordances.

Figure 3-1-1 is the dendrogram depicting the hierarchical clustering results. Based on this dendrogram, we chose three clusters as the most appropriate number of clusters because they demonstrate significant amount of between-group distance, while the distance among members within a cluster is small. Furthermore, each cluster includes a meaningful number of members. Table 3-1-2 represents the number of users in each cluster and the average number of affordance

actualizations for each cluster. In addition, Figure 3-1-2 represents the average number of affordance actualizations in each of the three clusters.

Table 3-1-2. The population and average affordance actualization for each cluster

Cluster Number	Population	Content Access Affordance Actualization (Mean)	Submission Affordance Actualization (Mean)	Communication Affordance Actualization (Mean)	Practice Affordance Actualization (Mean)	Feedback Affordance Actualization (Mean)
Cluster 1	22 (54%)	103.9	12.8	8.0	223.5	18.5
Cluster 2	10 (24%)	173.3	13.6	15.8	159.2	11.9
Cluster 3	9 (22%)	89.9	4.9	10.2	8.0	3.8

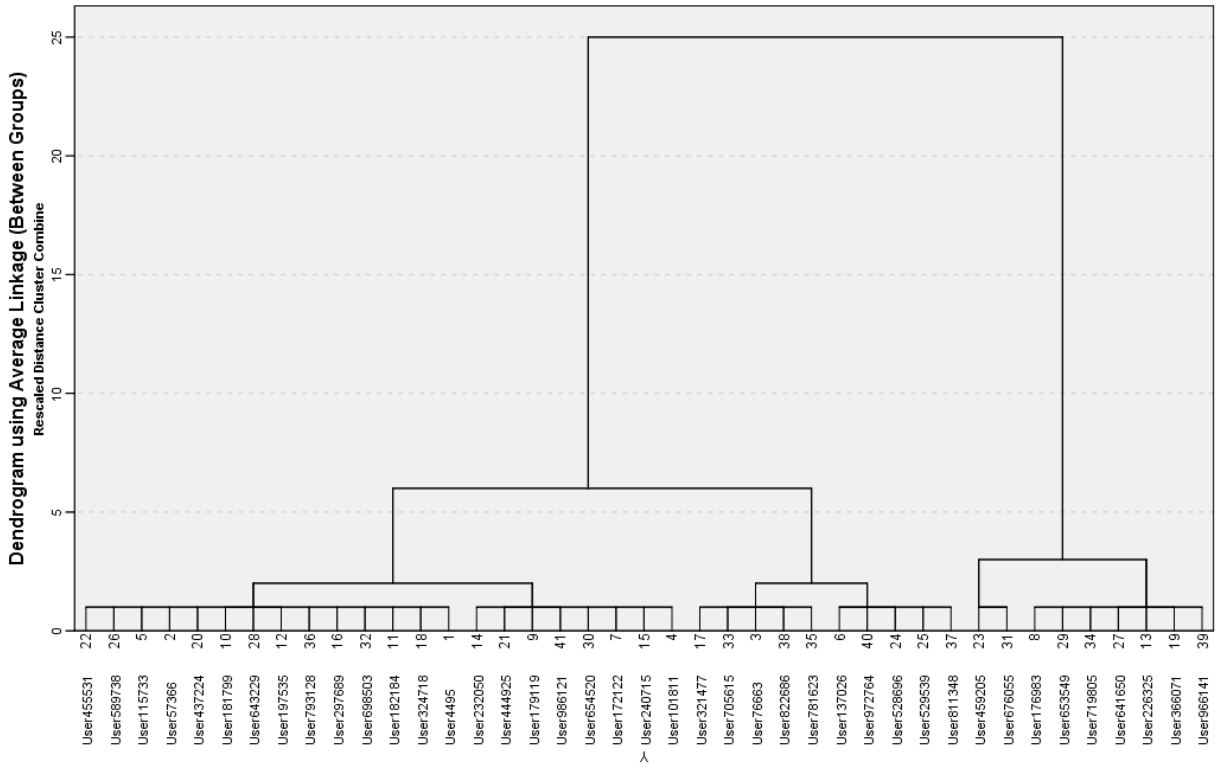

Figure 3-1-1. Dendrogram resulted from Hierarchical Cluster Analysis

Cluster 3, characterized as “minimalists”, comprises 22% of the sample. Users in this cluster mostly actualize affordances of Moodle at the minimum required to fulfill their course duties. They actualize four of the five affordances in significantly lower levels than other clusters. Communication is the only affordance they actualize in comparable levels to the other clusters.

Interestingly, the Communication affordance does not seem to have much variance across the three clusters.

Cluster 2, characterized as “Content Focused”, comprises 24% of the sample. The use of Moodle in this cluster is highly focused on actualizing Content Access affordances, and somewhat oriented towards Submission and Communication affordances. Although they meaningfully actualize the Practice and Feedback affordances of Moodle, these seem to be peripheral to their Moodle usage.

Cluster 1, characterized as “Practice Focused”, comprises the largest cluster, comprising 54% of the users in the sample. Their use of Moodle is highly focused on actualizing Practice affordances, and somewhat oriented towards Feedback affordances. Although they actualize Content Access and Submission affordances at a significant level, these seem to be relatively peripheral to the purposes for which they use Moodle.

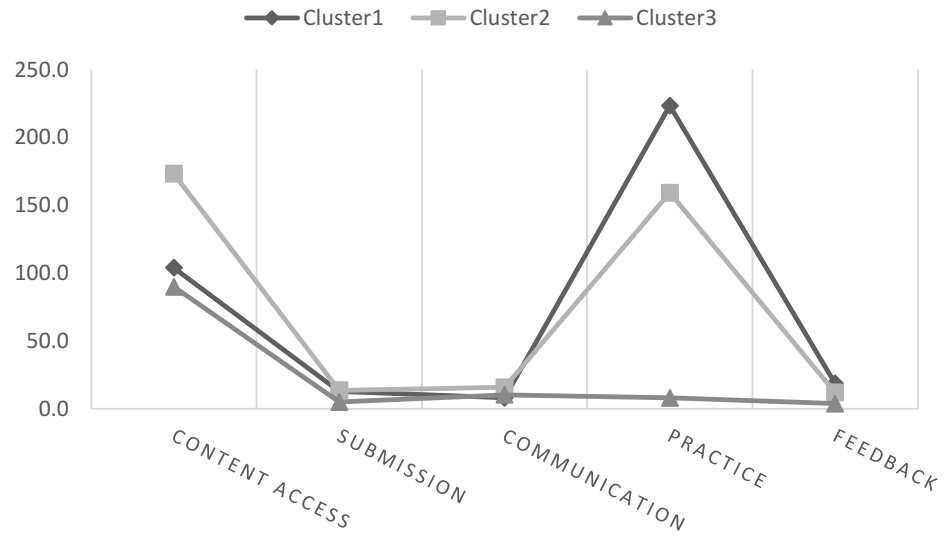

Figure 3-1-2. Average number of affordance actualizations per cluster

Figures 3-1-3 and 3-1-4 depict affordance actualization levels for each member of the three different clusters. Figure 3-1-3 compares how actualization of Content Access and Practice affordances are relatively different across the three clusters. While Cluster 1 very much depends on Practice affordances rather than Content Access affordances, members of Cluster 2 demonstrate relatively comparable dependency on the two affordances. Users of the Cluster 3

very much depend on Practice affordance compared to the Content Access affordance of Moodle.

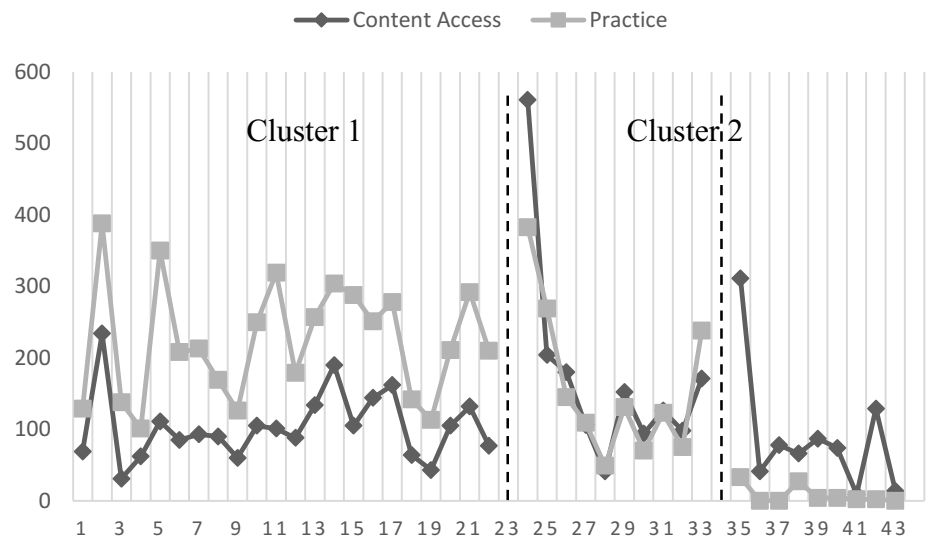

Figure 3-1-3. Number of affordance actualizations for each user of the three clusters

Figure 3-1-4 compares the actualization of the three other affordances across the three clusters. While Cluster 1 relatively depends more on Submission affordances than on Feedback affordances, Cluster 2 depends almost similarly on the two affordances, and Cluster 3 relatively depends more on Feedback than Submission. The Communication affordance seems to be equally actualized across the three clusters; users of all the three clusters appear to use Communication affordances at comparable levels, which are generally in between their levels of usage of the Submission and Feedback affordances.

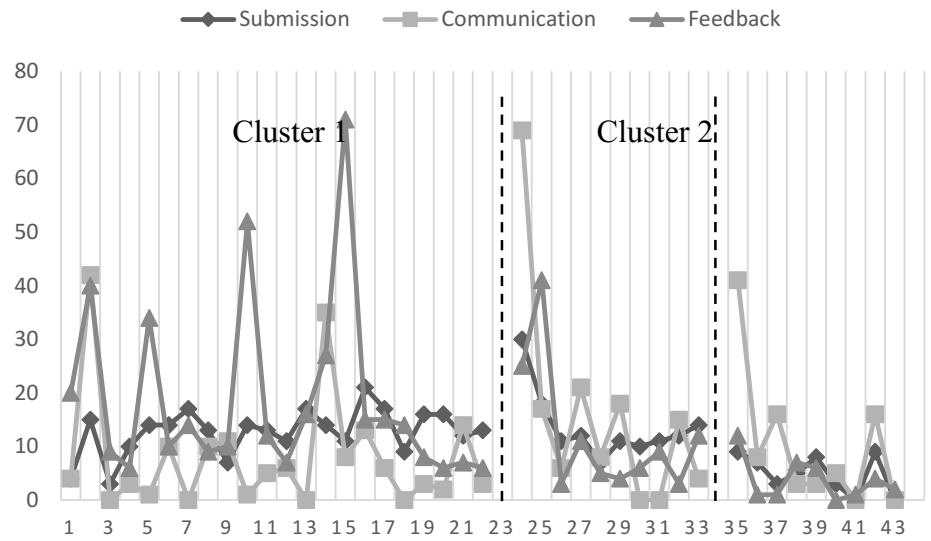

Figure 3-1-4. Number of affordance actualizations for each user of the three clusters

APPENDIX 3-2. INTERVIEWEES' DEMOGRAPHICS AND EXPERIENCE WITH MOODLE

Student Code	Gender	Major(s)	Year in School[3]	Number of Courses Completed Using on Moodle (including current semester)	Number of Moodle visits per week/course	Time spent on Moodle per day
ST1	Female	Accountancy	2nd year	5-7	7	2-3 hours
ST2	Female	BTM[4]	2nd year	8	7	30 min
ST3	Female	Marketing & BTM	1st year	6	3	30 min
ST4	Female	International Business & Marketing	1st year	5	3	30 min
ST5	Male	Accountancy	2nd year	13	4-5	15 min
ST6	Male	Marketing	3rd year	7-10	2	20-30 min
ST7	Male	Finance	3rd year	10 or more	3	5-30 min
ST8	Male	BTM	3rd year	Majority	7	20 min
ST9	Female	Marketing	2nd year	9	2	15 min
ST10	Female	Accountancy	1st year	6-7	7	5-10 min
ST11	Male	Finance	3rd year	5 or more	20	30 min
ST12	Male	International Business	4th year	12	4-5	10-15 min
ST13	Female	Accountancy	3rd year	20	7	15 min
ST14	Male	Marketing	3rd year	7	2	10 min
ST15	Male	Marketing	3rd year	10	2	15 min
ST16	Female	HR Management	3rd year	25	3	10 min
ST17	Male	BTM	3rd year	10	20	15 min

[3] In Quebec, 1st year is equivalent to the sophomore year in the US, and 2nd year to the junior year.
[4] Business Technology Management

APPENDIX 3-3. MOODLE ACTIONS MENTIONED AND AFFORDANCES INDICATED BY THE INTERVIEWEES

Possible Low-level Moodle Actions Mentioned in Interviews (Open Codes)	Affordances Indicated by Actions (Axial Codes)
Accessing information Accessing documents Accessing PowerPoints-slides Accessing material Accessing notes-lectures Accessing assignment-homework-case Accessing course outline Checking audio-video Accessing files Accessing resources Using library link to search article Checking the e-book Checking events Checking announcements	Content Access
Doing practice quizzes-tests Checking the time on the quiz	Practice
Checking grades Getting feedback on quizzes Checking feedback on submissions	Feedback
Sending-Checking messages Checking-Posting on forum Communicating with others Responding others' questions-posts Asking question from others Having discussion-exchange with others Talking-explaining to others Chatting with others Sharing ideas with others Contacting-telling others Looking up-checking other students-participants Having conversation-debate with others Getting the answer to your question Passing information to others Keeping in touch with others Finding group-mates	Communication
Submitting assignments-files Modifying-Resubmitting your submission	Submission

Checking submission status Doing graded quizzes tests	
Getting email announcements-communications Getting email-popup notifications	Receive Notification
Editing personal profile	Personalization

APPENDIX 3-4. IDENTIFIED MOODLE AFFORDANCES, THEIR DEFINITIONS, AND SUPPORTING STUDENT QUOTATIONS

Moodle Affordances	Examples of Supporting Student Quotes
Content Access: Action possibilities enabling the students to access any course content that they need; these possibilities give the students read-only access to the course-related material	• "I would get the PowerPoints, the documents that I need for, like, every class." (ST1) • "For each class, it's where you find all the notes for it, cuz you are not gonna get anything physical in class." (ST2) • "It's gonna be where you are going to get all the class notes" (ST3) • "I can download the PowerPoints of the next lecture so I can print them and have them during the lecture. I can check the outline to be aware of the deadlines" (ST4) • "Normally, when I use Moodle the most often times it's just to check the course outline." (ST5)
Submission: Action possibilities enabling the students to submit their work, answers, or ideas for part of their course grade, for which they might or might not receive subsequent feedback	• "I had one prof who used that we submitted lots of assignments, like ten assignments, on Moodle whereas others never submit an assignment on it." (ST2) • "I find that being able to submit it online at your own time, and even if you finish it a week early you can submit it a week early and it's completely fine. So I find that submitting the assignments is a big plus, because not only does it save the paper, there is less printing, less I have to get there on-time, it's less stress on the student if you can just submit it when you can directly online." (ST3) • "Sometime you can like put document in a folder, so that the teacher can see it on Moodle… the teacher creates a folder and you put like notes that he asked for on it" (ST4) • "A few of my classes, instead of handing in a physical copy of an assignment, you would upload it onto Moodle … I am pretty sure, if you submit it early you can resubmit it, stuff like that. No concern about it, if you think you don't have enough time on it, you just upload it, and if you do have time to look over it again, you correct the little mistakes you made in here, then you can upload it." (ST5)
Communication: Action possibilities enabling the students to communicate and share their ideas, opinion, and questions with the teacher, teaching assistants or fellow	• "I use Moodle to communicate with my teacher, because we have something called announcements, or personal message that I can send to the teacher." (ST1) • "In middle school, we sometimes chat our prof to ask something, like during class while we were working in a group ... kind of where you can ask a question but not in front of everyone; so that was definitely like a positive experience." (ST2) • "Moodle is your portal to talk to the teacher … You can send messages to the teacher through Moodle, and teacher can also post notes on the

classmates; or to acquire awareness of what the teacher, teaching assistants or classmates communicated or shared; both parties have the chance to express themselves and engage in two-way interaction	Moodle page to let you know about announcements such as cancelled classes or cancelled quizzes or extra information regarding exams … Some people also use the forum to talk to each other, but it's very rare that it's being used." (ST3) • "We can communicate with classmates … I check my courses if I have messages, like if some classmate sent me messages." (ST4) • "Moodle is, I guess, just a tool to facilitate communication between the professor and the students." (ST5)
Practice: Action possibilities enabling the students to practice what they have already learned about the course material	• "I would do practice questions, some teachers put practice questions on Moodle. So, I usually use it [Moodle] for those kind of stuff." (ST1) • "I had the one prof who we had quizzes on Moodle, whereas other who we had quizzes through like the course textbook website." (ST2) • "For example quizzes. Some teacher do it in class which is fine, but I find it waste a lot of class time which could be used for answering questions and preparing for upcoming midterm and finals. What other teachers do is using quizzes online which I find it very nice because you could do it in your own time, you can prepare." (ST3) • "You can do test there … We can do training test … We have like practice quiz that we can do before that [class]." (ST4) • "I tend to prefer having the online quizzes, because I see them as being more practice than evaluation. I don't think they have ever said, with these quizzes, you can't use your notes." (ST5)
Feedback: Action possibilities enabling the students to get feedback on their learning, participation, submitted work, or status or progress in the course	• "Let's say I do a quiz on multiple choice [questions], they [Moodle] would tell me what's wrong, if I got the right answer or not." (ST1) • "I had a prof who they actually said like our grade for the quizzes and our grade for the midterm, and it was all on Moodle, and it's nice to like actually know." (ST2) • "Grades [section on Moodle] is to know what you got in either the class participation or on the assignment you submitted." (ST3) • "I like having the feedback, having grades along the way." (ST5)

APPENDIX 3-5. NAMES OF 53 ACTIONS FROM MOODLE LOGS AND THEIR FINALIZED DEFINITIONS AFTER TWO ROUNDS OF CARD SORTING, AND THE AFFORDANCES THAT THEY ACTUALIZE

Affordance	Action Name	Final Revised Action Definition
Communication Affordance	discussion_mark read	Marking a forum discussion as read
	forum_add discussion	Posting a new discussion to a forum
	forum_add post	Replying to an existing discussion on a forum
	forum_delete discussion	Deleting your discussion on a forum
	forum_delete post	Deleting your post on a forum
	forum_subscribe	Subscribing to a forum
	forum_unsubscribe	Unsubscribing from a forum
	forum_update post	Updating/changing your post on a forum
	forum_view discussion	Visiting one of the discussions on a forum
	forum_view forum	Visiting the first page of a forum
Content Access Affordance	assign_view (before submission)	Visiting the main page of an assignment (the one with instructions and status of your submission), before submitting the assignment
	assign_view all	Visiting the page for all assignments
	book_view	Visiting a book page
	book_view all	Visiting the page for all books
	book_view chapter	Visiting chapters of a book
	course_view	Visiting the main page of the course website
	data_view	Visiting any of the pages of a Moodle database
	folder_view	Visiting a folder
	folder_view all	Visiting the page for all folders
	imscp_view all	Visiting the page that lists all multimedia content
	label_view all	Visiting the page that list titles of all course content
	lti_launch	Opening an external tool (e.g. electronic textbook)
	lti_view all	Visiting the page that lists all external tools (e.g. electronic textbook)
	page_view	Visiting a dedicated page with specific information (e.g. cases, activity, etc.)
	page_view all	Visiting the page that lists all dedicated pages with specific information (e.g. cases, activity, etc.)
	quiz_view (for graded quizzes)	Visiting the main page of a graded quiz (the one with instructions about the quiz)

Affordance	Action Name	Final Revised Action Definition
	resource_view	Accessing a file on Moodle (e.g. slides, documents, etc.)
	resource_view all	Visiting the page that lists all downloadable files (e.g. slides, documents, etc.)
	url_view	Visiting a website link provided on Moodle
	url_view all	Visiting the page that list all website links provided on Moodle
Feedback Affordance	assign_view (after submission)	Visiting the main page of an assignment (the one with instructions and status of your submission), after submitting the assignment
	quiz_review (for practice quizzes)	Reviewing a practice quiz and your answers after you are finished
	quiz_review (for graded quizzes)	Reviewing a graded quiz and your answers after you are finished
	quiz_view all	Visiting the page that lists all quizzes (whether practice or graded) with your scores, if available
	quiz_view summary (for practice quizzes)	Checking the summary of your answers to a practice quiz
	quiz_view summary (for graded quizzes)	Checking the summary of your answers to a graded quiz
Practice Affordance	quiz_attempt (for practice quizzes)	Starting to do a practice quiz
	quiz_close attempt (for practice quizzes)	Submitting your answers to a practice quiz once you are finished
	quiz_continue attempt (for practice quizzes)	Continuing to the next question of a practice quiz
Submission Affordance	assign_submission statement accepted	Accepting the submission statement ("This assignment is my own work, except where I have acknowledged the use of the works of other people.")
	assign_submit	Submitting an assignment
	assign_view submit assignment form	Visiting the page to upload files for your assignment
	data_add	Posting to a Moodle database
	data_update	Updating/changing your post on a Moodle database
	quiz_attempt (for graded quizzes)	Starting to do a graded quiz
	quiz_close attempt (for graded quizzes)	Submitting your answers to a graded quiz once you are finished
	quiz_continue attempt (for graded quizzes)	Continuing to the next question of a graded quiz
Actions not assigned to	course_recent	Visiting the page that lists your recent activities in Moodle

Affordance	Action Name	Final Revised Action Definition
any affordance (or too problematic during card sorting)	forum_search	Searching within the forums
	forum_view forums	Visiting the page that lists all forums
	quiz_view (for practice quizzes)	Visiting the main page of a practice quiz (the one with instructions about the quiz)
	user_view	Visiting someone's user profile
	user_view all	Viewing the list of all participants in the Moodle course

APPENDIX 3-6. INTER-RATER AGREEMENT FOR THE FIRST ROUND OF CARD SORTING EXERCISE (5 JUDGES, 53 ACTIONS)

Action Code	Content Access	Submission	Communication	Practice	Feedback
assign_submission statement accepted	0	5	0	0	0
assign_submit	0	5	0	0	0
assign_view (after submission)	0	1	0	0	4
assign_view (before submission)	5	0	0	0	0
assign_view all	5	0	0	0	0
assign_view submit assignment form	0	5	0	0	0
book_view	5	0	0	0	0
book_view all	5	0	0	0	0
book_view chapter	5	0	0	0	0
course_recent	3	0	0	0	2
course_view	5	0	0	0	0
data_add	0	4	0	1	0
data_update	0	5	0	0	0
data_view	4	0	0	1	0
discussion_mark read	1	0	3	0	1
folder_view	5	0	0	0	0
folder_view all	5	0	0	0	0
forum_add discussion	0	1	4	0	0
forum_add post	0	0	5	0	0
forum_delete discussion	0	1	4	0	0
forum_delete post	0	0	5	0	0
forum_search	2	0	3	0	0
forum_subscribe	0	1	4	0	0
forum_unsubscribe	0	0	5	0	0
forum_update post	0	1	4	0	0
forum_view discussion	1	1	3	0	0
forum_view forum	4	0	1	0	0
forum_view forums	3	0	2	0	0
imscp_view all	5	0	0	0	0
label_view all	5	0	0	0	0

lti_launch	5	0	0	0	0
lti_view all	5	0	0	0	0
page_view	5	0	0	0	0
page_view all	5	0	0	0	0
quiz_attempt (for graded quizzes)	0	5	0	0	0
quiz_attempt (for practice quizzes)	0	0	0	5	0
quiz_close attempt (for practice quizzes)	0	0	0	5	0
quiz_close attempt (for graded quizzes)	0	5	0	0	0
quiz_continue attempt (for practice quizzes)	0	0	0	5	0
quiz_continue attempt (for graded quizzes)	0	5	0	0	0
quiz_review (for practice quizzes)	0	0	0	0	5
quiz_review (for graded quizzes)	0	0	0	0	5
quiz_view (for practice quizzes)	1	0	0	4	0
quiz_view (for graded quizzes)	3	2	0	0	0
quiz_view all	3	1	0	0	1
quiz_view summary (for practice quizzes)	0	0	0	1	4
quiz_view summary (for graded quizzes)	0	1	0	0	4
resource_view	5	0	0	0	0
resource_view all	5	0	0	0	0
url_view	5	0	0	0	0
url_view all	5	0	0	0	0
user_view	3	0	2	0	0
user_view all	4	0	1	0	0

The rows in yellow identify the actions sorted into affordances by agreement of less than 100% (5 out of 5)

APPENDIX 3-7. INTER-RATER AGREEMENT FOR THE SECOND ROUND OF CARD SORTING EXERCISE (10 JUDGES, 47 ACTIONS)

Action Code	Content Access	Submission	Communication	Practice	Feedback
assign_submission statement accepted	0	10	0	0	0
assign_submit	0	10	0	0	0
assign_view (after submission)	1	0	0	0	9
assign_view (before submission)	9	1	0	0	0
assign_view all	8	1	0	0	1
assign_view submit assignment form	0	10	0	0	0
book_view	10	0	0	0	0
book_view all	10	0	0	0	0
book_view chapter	10	0	0	0	0
course_recent	5	0	0	0	5
course_view	10	0	0	0	0
data_add	0	10	0	0	0
data_update	0	10	0	0	0
data_view	10	0	0	0	0
discussion_mark read	1	0	9	0	0
folder_view	10	0	0	0	0
folder_view all	10	0	0	0	0
forum_add discussion	0	0	10	0	0
forum_add post	0	0	10	0	0
forum_delete discussion	0	0	10	0	0
forum_delete post	0	0	10	0	0
forum_search	5	0	5	0	0
forum_subscribe	2	0	8	0	0
forum_unsubscribe	1	0	9	0	0
forum_update post	0	0	10	0	0
forum_view discussion	1	0	9	0	0
forum_view forum	1	0	9	0	0
forum_view forums	6	0	4	0	0
imscp_view all	10	0	0	0	0
label_view all	10	0	0	0	0
lti_launch	10	0	0	0	0
lti_view all	10	0	0	0	0

page_view	10	0	0	0	0
page_view all	10	0	0	0	0
quiz_attempt (for graded quizzes)	0	9	0	1	0
quiz_attempt (for practice quizzes)	0	0	0	10	0
quiz_close attempt (for practice quizzes)	0	0	0	10	0
quiz_close attempt (for graded quizzes)	0	10	0	0	0
quiz_continue attempt (for practice quizzes)	0	0	0	10	0
quiz_continue attempt (for graded quizzes)	0	10	0	0	0
quiz_review (for practice quizzes)	0	0	0	2	8
quiz_review (for graded quizzes)	0	0	0	1	9
quiz_view (for practice quizzes)	6	0	0	4	0
quiz_view (for graded quizzes)	9	1	0	0	0
quiz_view all	1	0	0	0	9
quiz_view summary (for practice quizzes)	0	0	0	1	9
quiz_view summary (for graded quizzes)	0	0	0	0	10
resource_view	10	0	0	0	0
resource_view all	10	0	0	0	0
url_view	10	0	0	0	0
url_view all	10	0	0	0	0
user_view	3	0	7	0	0
user_view all	5	0	5	0	0

- The rows in yellow identify the actions sorted into affordances by agreement of less than 100% (5 out of 5 judges) but equal or higher than 80% (8 out of 10 judges).
- The rows in grey identify the actions sorted into affordances by agreement of less than 80% (8 out of 10 judges), and so removed from the data analysis.

APPENDIX 3-8. CREATING QUANTITATIVE PERSONAS USING PCA

Table 3-8-1. PCA communalities

Actions	Initial	Extraction
Calendar event created	1.000	.326
Calendar event deleted	1.000	.159
Calendar event updated	1.000	.617
Choice made	1.000	.241
Choice updated	1.000	.043
Course module instance list viewed/Forum	1.000	.011
Course module instance list viewed/Quiz	1.000	.022
Course module viewed/Choice	1.000	.272
Course module viewed/File	1.000	.386
Course module viewed/Folder	1.000	.158
Course module viewed/Forum	1.000	.516
Course module viewed/Quiz	1.000	.770
Course module viewed/URL	1.000	.078
Course searched	1.000	.031
Course user report viewed	1.000	.002
Course viewed	1.000	.779
Discussion viewed	1.000	.570
Grade overview report viewed	1.000	.128
Grade user report viewed	1.000	.371
Quiz attempt reviewed	1.000	.722
Quiz attempt started	1.000	.857
Quiz attempt submitted	1.000	.818
Quiz attempt summary viewed	1.000	.725
Quiz attempt viewed	1.000	.820
Scheduler booking added	1.000	.829
Scheduler booking form viewed	1.000	.737
Scheduler booking removed	1.000	.529
User graded	1.000	.802
User list viewed	1.000	.245
User profile viewed	1.000	.277
User report viewed	1.000	.014

Extraction Method: Principal Component Analysis.

Table 3-8-2. Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.263	23.428	23.428	7.263	23.428	23.428	6.118	19.735	19.735
2	3.635	11.726	35.154	3.635	11.726	35.154	3.884	12.529	32.264
3	1.957	6.313	41.466	1.957	6.313	41.466	2.853	9.202	41.466
4	1.761	5.681	47.147						
5	1.382	4.458	51.605						
6	1.274	4.109	55.714						
7	1.263	4.076	59.790						
8	1.117	3.602	63.392						
9	1.074	3.466	66.858						
10	1.017	3.281	70.139						
11	.997	3.216	73.355						
12	.978	3.153	76.508						
13	.874	2.818	79.326						
14	.818	2.639	81.965						
15	.762	2.458	84.424						
16	.717	2.314	86.738						
17	.683	2.204	88.941						
18	.534	1.721	90.662						
19	.468	1.510	92.172						
20	.419	1.352	93.524						
21	.375	1.210	94.734						
22	.345	1.115	95.849						
23	.324	1.044	96.893						
24	.308	.994	97.887						
25	.192	.620	98.507						
26	.152	.489	98.996						
27	.107	.346	99.342						
28	.095	.305	99.647						
29	.059	.190	99.838						
30	.033	.106	99.944						
31	.017	.056	100.000						

Extraction Method: Principal Component Analysis.

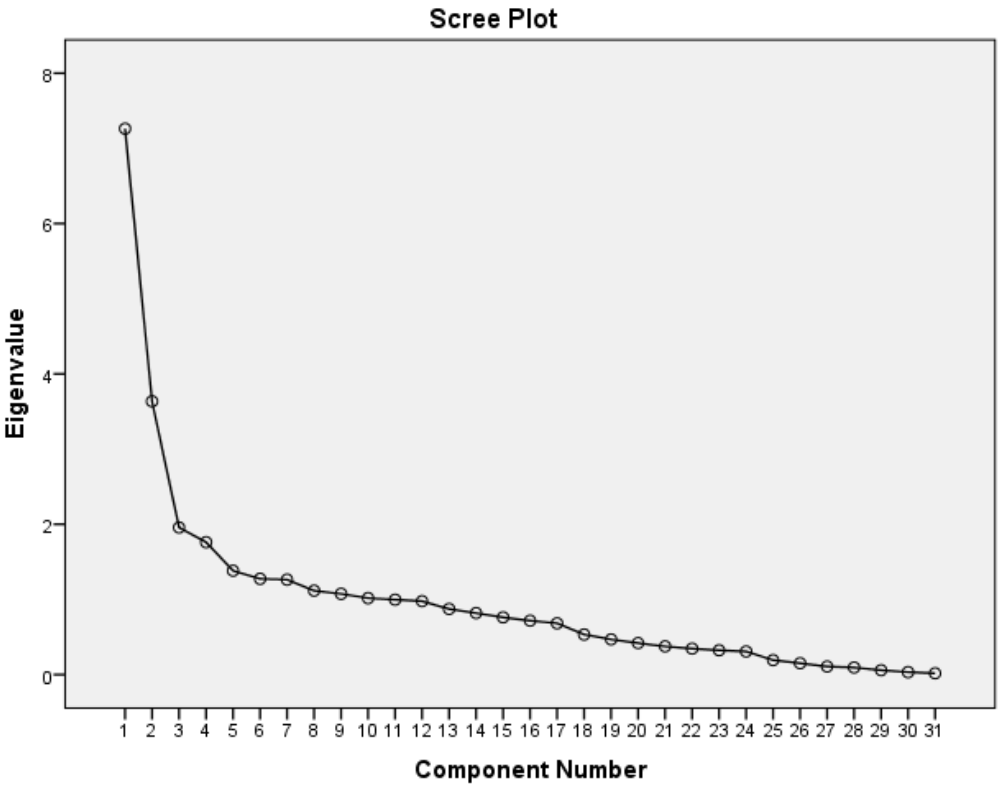

Figure 3.8.1. The scree plot for eigenvalues of each component

Table 3-8-3. Rotated component matrix[a]

Actions	Component		
	PC1	PC2	PC3
Calendar event created		.565	
Calendar event deleted		.378	
Calendar event updated		.780	
Choice made		.402	
Choice updated			
Course module instance list viewed/Forum			
Course module instance list viewed/Quiz			
Course module viewed/Choice	.304	.411	
Course module viewed/File	.409		.396
Course module viewed/Folder		.314	
Course module viewed/Forum			.711
Course module viewed/Quiz	.828		
Course module viewed/URL			
Course searched			
Course user report viewed			
Course viewed	.568	.312	.598
Discussion viewed			.732
Grade overview report viewed			.340
Grade user report viewed			.549
Quiz attempt reviewed	.779		.306
Quiz attempt started	.920		
Quiz attempt submitted	.900		
Quiz attempt summary viewed	.845		
Quiz attempt viewed	.901		
Scheduler booking added		.910	
Scheduler booking form viewed		.841	
Scheduler booking removed		.715	
User graded	.892		
User list viewed			.494
User profile viewed			.503
User report viewed			

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Loadings less than 0.3 are supressed
a. Rotation converged in 4 iterations.

Table 3-8-4. Component transformation matrix

Component	1	2	3
PC1	.846	.361	.393
PC2	-.467	.858	.216
PC3	-.259	-.366	.894

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Table 3-8-5. Mean frequency for each action

Action	Mean Frequency
Calendar event created	0.1
Calendar event deleted	0.0
Calendar event updated	1.4
Choice made	1.3
Choice updated	0.5
Course module instance list viewed/Forum	0.0
Course module instance list viewed/Quiz	0.0
Course module viewed/Choice	13.5
Course module viewed/File	68.5
Course module viewed/Folder	2.3
Course module viewed/Forum	7.3
Course module viewed/Quiz	51.3
Course module viewed/URL	0.3
Course searched	0.0
Course user report viewed	0.0
Course viewed	132.2
Discussion viewed	12.4
Grade overview report viewed	1.0
Grade user report viewed	13.6
Quiz attempt reviewed	18.4
Quiz attempt started	13.2
Quiz attempt submitted	8.6
Quiz attempt summary viewed	11.6
Quiz attempt viewed	357.9
Scheduler booking added	0.4
Scheduler booking form viewed	2.3
Scheduler booking removed	0.1
User graded	16.6
User list viewed	3.2
User profile viewed	0.5
User report viewed	0.0

APPENDIX 3-9. ASSESSING THE THREE QUALITATIVE PERSONAS IN OUR SAMPLE OF 17 INTERVIEWEES

Persona	Interviewees	Quotations
Miss Dependent	ST1 ST5 ST8 ST9 ST11 ST13	• "If anyone ask something to the teacher and it's public to the classmates, I would get a notification on that but not for grades or if a teacher post a new document without saying it in the announcements, nothing like that. So I would prefer if they… The notification system is much better." (ST1) • "I would get the PowerPoints, the documents that I need for like every class so I would print that out. I would do practice questions. Some teachers put practice questions on Moodle so I usually use it for those kind of stuff, quizzes, yeah that's it." (ST1) • "It would be nice to you know… to be able to use it to actually see how you're doing but a lot of the professors don't use that feature." (ST5) • "I know that I like it more than FirstClass because the information for the class you were looking into, it's all right there on the same page type of thing like it shows you the schedule and like, you know, the links are easy to find and easy to see like what kind of document it is going to open and stuff like that. But as a result, there is also just a lot of information being thrown at you at the same time which can make it like a bit more confusing or daunting to use." (ST5) • "you have to access those resources in Moodle in order to get all the materials. Sometimes there are two things that people do, which is like if the instructor uploads all the resources for the whole semester, some students download all the resources so that they don't need to access Moodle again so that they can do it locally from their computer to access files. Sometimes some students when they have access to internet like almost every time using their tablets or other devices, they usually don't download and that's how they access Moodle." (ST8) • "I think what I don't like is sometimes when the teacher posts something, it doesn't like notify you. Sometimes it does if you want to subscribe maybe. Sometimes you can choose that but sometimes it's annoying because when you subscribe you subscribe on everything. So I would feel like some students if they're not up to date they would miss a lot of stuff. But that's one of the stuff I don't really like that you have to be checking and then teacher would be like "no I posted this" and you're like "no"." (ST9)

Persona	Interviewees	Quotations
		• "Moodle is like the outline, the guide for you to understand this course and you can find the PowerPoint, you can find the outline on it. The teacher will upload.' (ST11) • "PowerPoint is most important in our course. For example, in one course, our teacher will give us maybe six or seven powerpoints or files, her teacher will just give two. So our teacher will post more." (ST11) • "I think that Moodle is a tool for you to say what you need to learn each week and all the resources you needed about the course is online and it's not very hard to use it." (ST13)
Mr. Cue-Conscious	ST2 ST3 St7 St10 St15 ST16	• "It is kind of nice to be even able to know your grade like assets… because I had one prof who actually said like our grade for our quizzes are grade for midterm are all on Moodle and it's nice to like actually know because a lot of the times I am just like guessing what my grade is." (ST2) • "I don't even know if the chat feature exist anymore because I've never used it." (ST2) • "I know there is an assignment due for a certain date, it's not going to show up on the calendar and I can't add it myself so I can't put it in my own stuff but I think it would be nice for students to be able to have." (ST3) • "If a professor post a grade for the assignment, I go on Moodle. I open the page. I will view my grades and that's it. That's it. If it's not there he didn't upload it. So I mean, there is no need in communicating with the professor." (ST7) • "You get emails whenever someone comments, but you don't know if the comments are … related to your post or someone else's post. And if it's someone else's post really we don't really care." (ST10) • "I see that sometimes teachers give hints and things over the forum that they don't mention in class or even discussions between students. I have found them sometimes useful and they'll talk about their experience at the midterm exam. I'll take all that into account when I study for the final." (ST15) • "If I have a grade that's about to commence that's the first thing I'm going to do. I'm going to go on the side of the panel and then I'm going to go ahead and look for the grade. If the grades are not posted, I'm just going to check if he has posted anything new material for the next coming class and then I'm going to go ahead and just print that out. So that's my ritual thing that I always do, my routine." (ST16)
Mr. Personal Journey	ST4 ST6	• "I prefer to use the [Piazza] application on my like mobile devices because I have like all the feedbacks and I get

Persona	Interviewees	Quotations
	ST12 ST14 ST17	notified when someone ask good question and that really help me when I wanted to install SAP. So yeah I feel like it's kind of interesting and useful." (ST4) • "I feel forums are very… they are very useful. I mean, sometimes when a student explains something to you, it might be more clear than when the professor explains. I think there are different approaches of explaining some things to certain people or in different ways." (ST6) • "when you click on the class, you can find also all the participants in the class so all the students and sometimes it was really useful for me because I didn't know anybody in the class and just to contact somebody to get some information, you know so you can know with who you're studying, who you're studying with." (ST12) • "I needed to participate in a forum discussion so this is kind of a very interesting experience for me myself because some people they don't like to participate but for me I really think that as a business student you need to participate. Needed to read articles and share with others so I think it's a very good experience for me." (ST14) • "And all the students that were in the same class were able to comment on it and basically communicate with each other and essentially balanced ideas off each other in regards to what was happening. So I mean, I like the fact that you were able to do that so you are communicating with the students that you wouldn't otherwise communicate with but it was very impersonal in regards to like sure I'm communicating with, let's say Peter Smith or something or you know, whoever the name was but you actually don't… you're not forced to have a picture or a name as a real name so I mean it could have been someone else that I've been talking to or you know, or you have a name but you don't have a face to the name so it was very impersonal that way. But I mean like for what it's worth the communication still happens, so yeah. It's actually very interesting, actually because I've never done that before" (ST17)

APPENDIX 3-10. IDENTIFYING PERSONAS USING A DIVERSE DATASET OF 23 SECTIONS

We collected Moodle log data for 2,393 students of 23 sections of three introductory business courses; this includes the 456 students in 4 sections of one course included in our primary dataset reported in this study. The dataset records over 1.6 million actions in Moodle for a total of 2,393 students registered. The three courses were deliberately chosen for the following reasons. First, they used Moodle extensively and in somewhat similar ways; they posted course content, ran weekly quizzes, used forums, put assignments and accepted submissions on Moodle, and provided grades there. Second, they are coordinated courses with several sections each, so all the sections of each course use the same Moodle template; that is, each course provided the same content in the same format. Furthermore, some sections taught by the same professor used a shared Moodle website, as if students are in the same class section.

However, the reason we did not report this analysis as our primary one is that there were yet differences in the implementation and use of Moodle among various courses that could not be controlled for analytically. Among such differences were the number of practice and graded quizzes available, the number of questions per quiz, the number of assignments provided, and the number of voluntary and mandatory forums available.

The data for 15 of the sections is collected for Fall 2015 semester, 3 are for Winter 2015, and 5 others are for the 2014 and 2013 school years; however, we made sure that a similar Moodle template had been used for the older data.

We followed the same analysis methodology as for the primary data analysis reported in the essay. Figure 3-10-1 is the dendrogram that depicts the hierarchical clustering results. We chose to cut the dendrogram tree at the height of 0.6 because it provides us with three major clusters that demonstrate a significant amount of between-group distance, while the distance among members within a cluster is small. Furthermore, each cluster includes a meaningful number of members. Small clusters with fewer than 140 members (6% of sample) are not considered as major clusters, so 552 users (23% of sample) are not part of any of the three clusters. This is different from the main study, in which 100% of the students were represented in the three clusters; this reflects the greater heterogeneity of the larger dataset. Table 3-10-1 represents the

number of users in each cluster and the average number of affordance actualizations for each cluster. Figures 3-10-2 and 3-10-3 represent the average number of actual and standardized affordance actualizations in each of the three clusters. While Figure 3-10-2 keeps the original scale to highlight the differences in the frequency of actualizations between the five affordances, Figure 3-10-3 standardizes the scale to focus on the differences between the three personas for each affordance.

Table 3-10-1. The population and average affordance actualization for each cluster

Clusters	Population	Mean Number of Actions Taken to Actualize Each Affordance				
		Content Access	Submission	Communication	Practice	Feedback
P1	648 (27%)	252.6	71.3	28.1	620.4	59.5
P2	458 (19%)	303.4	51.1	17.7	279.6	37.3
P3	735 (31%)	230.6	46.5	7.8	35.4	24.1
Other	552 (23%)	236.3	99.3	102.9	169.2	35.4
All	2393 (100%)	251.8	66.3	37.1	271.4	38.8
F (and p-value) for ANOVA mean differences		44.37 (.000***)	44.31 (.000***)	53.56 (.000***)	1235.00 (.000***)	185.40 (.000***)

* means p-value < 0.100; ** means < 0.050; *** means < 0.010

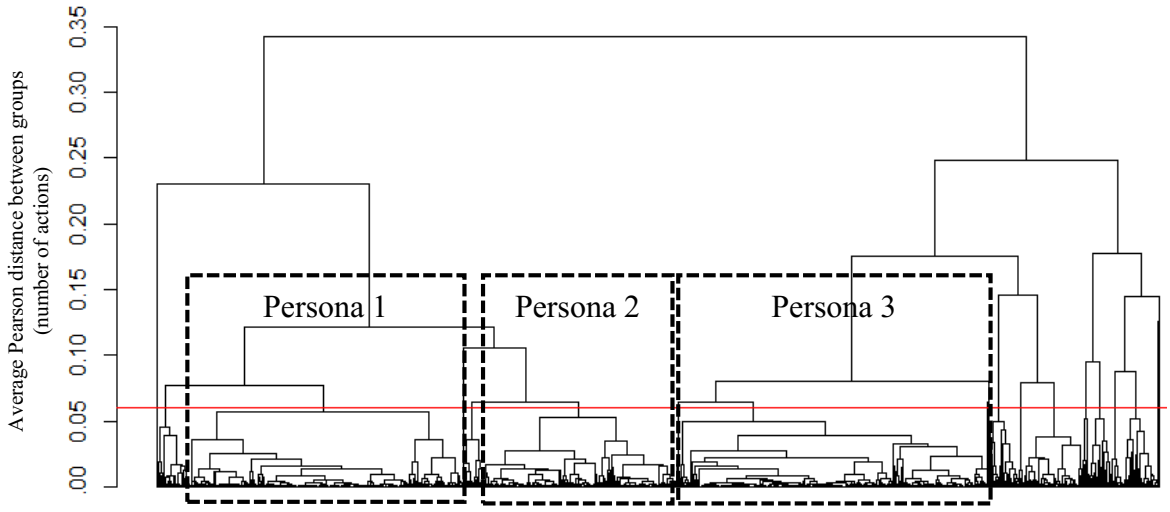

Figure 3-10-1. Dendrogram resulted from Hierarchical Cluster Analysis

Table 3-10-2. Tukey HSD test result for mean comparisons of affordance actualization

Affordance Actualization	Cluster (I)	Cluster (J)	Mean Difference (I-J)	Std. Error	P-value
Content Access	P1	P2	-50.77445	7.95815	.000***
		P3	21.96794	7.02482	.005***
	P2	P3	72.74239	7.76066	.000***
Submission	P1	P2	20.25473	3.10761	.000***
		P3	24.84218	2.74315	.000***
	P2	P3	4.58745	3.03049	.285
Communication	P1	P2	10.42037	2.22143	.000***
		P3	20.29178	1.96090	.000***
	P2	P3	9.87141	2.16630	.000***
Practice	P1	P2	340.85373	13.34960	.000***
		P3	584.99417	11.78395	.000***
	P2	P3	244.14044	13.01832	.000***
Feedback	P1	P2	22.21589	2.09054	.000***
		P3	35.36612	1.84536	.000***
	P2	P3	13.15022	2.03867	.000***

Sample size: 2393. * means p-value < 0.100; ** means < 0.050; *** means < 0.010

Persona 3 (P3) comprises 31% of the sample. Users in this cluster mostly actualize affordances of Moodle at the minimum required to fulfill their course duties. They actualize all of the five affordances in significantly lower levels than other clusters.

Persona 2 (P2) comprises 19% of the sample. The use of Moodle in this cluster is more highly focused on actualizing Content Access affordances than with other clusters. Although they meaningfully actualize the Practice and Feedback affordances of Moodle, they do so less so than the Persona 1 persona.

Persona 1 (P1) comprises 27% of the users in the sample. Their use of Moodle is highly focused on actualizing Practice affordances, and somewhat oriented towards Feedback affordances. Although they actualize the Content Access affordance at a significant level, they do so less than the Persona 2.

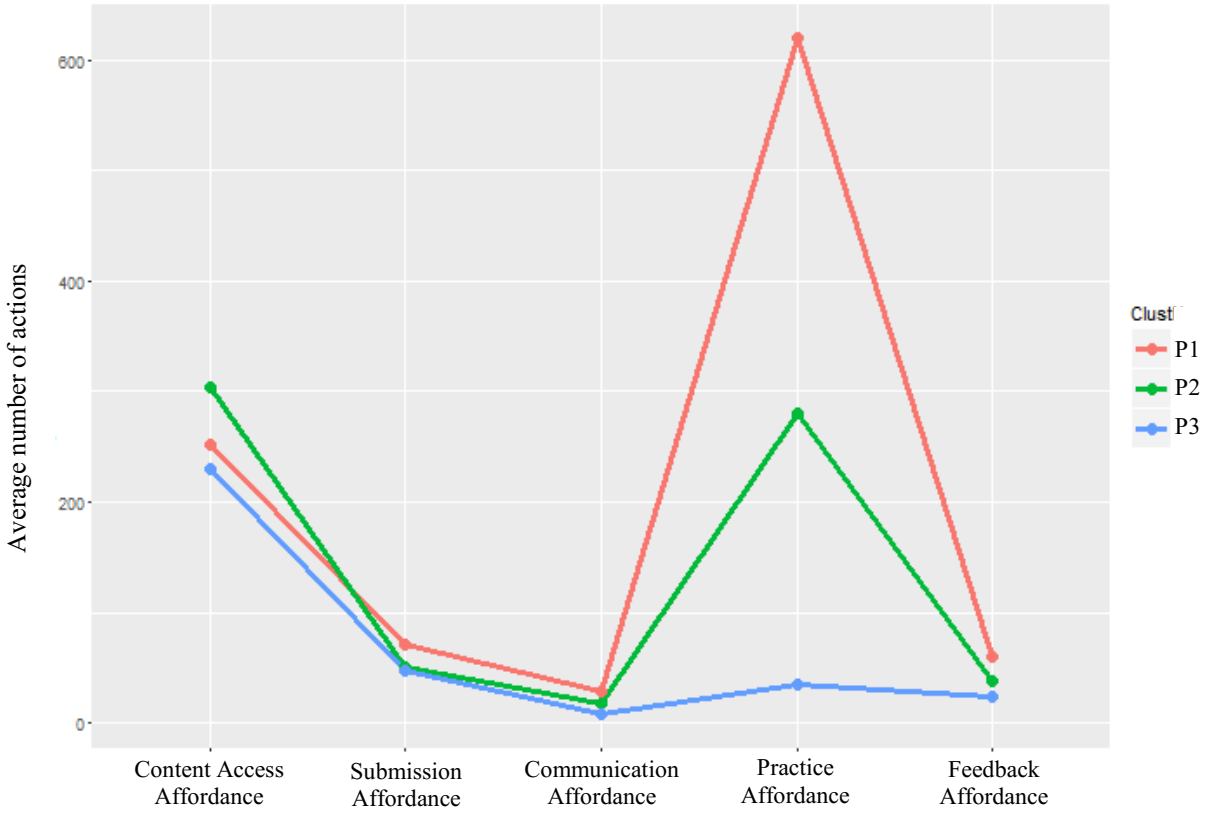

Figure 3-10-2. Average number of affordance actualizations across

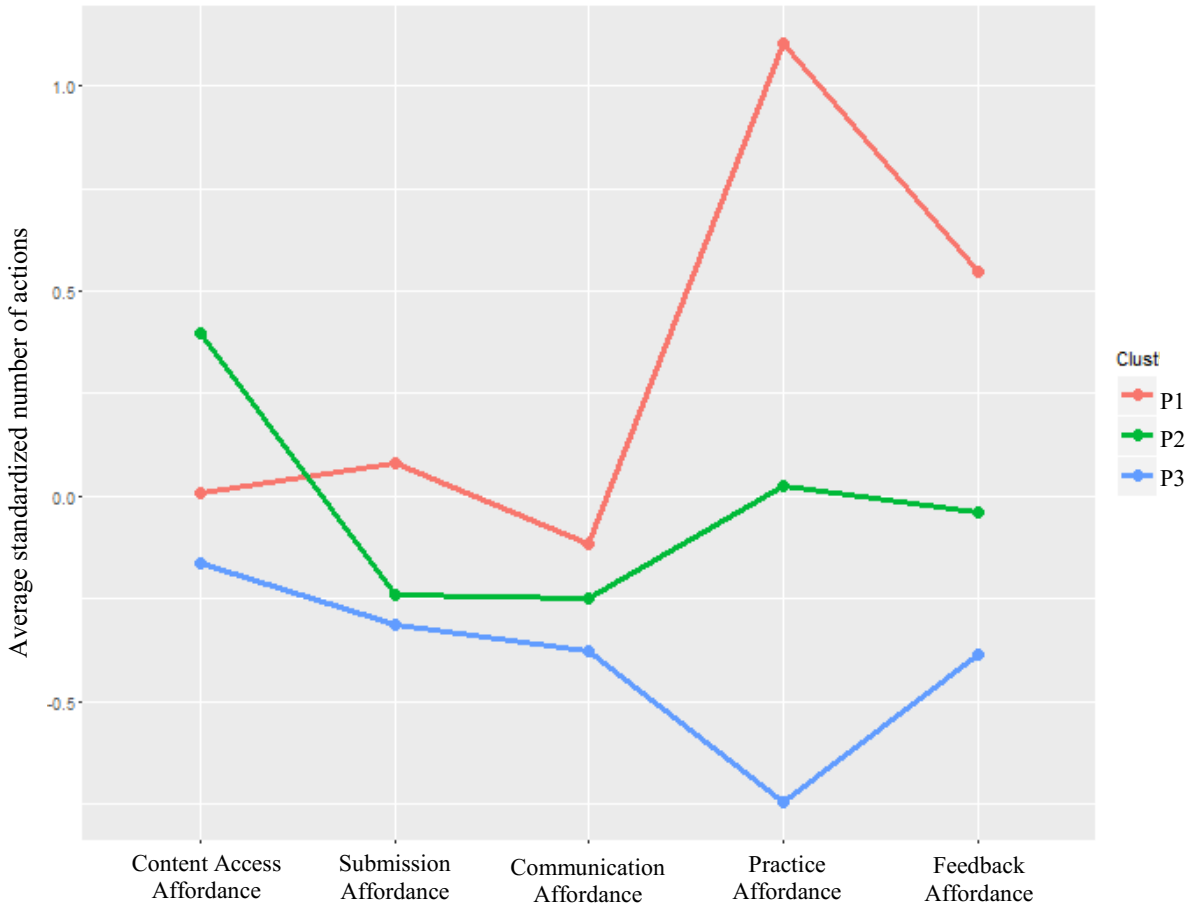

Figure 3-10-3. Average standardized number of affordance actualizations across personas

Figure 3-10-4 uses Kernel Density Estimation to visualize the expected distribution of student personas for each Moodle affordance. While the communication affordance barely differentiates the three personas, the practice affordance clearly distinguishes them. Tables 3-10-3 and 3-10-4 represent the contingency tables for members of the three personas across sections and instructors, respectively. With standard residuals higher than 1.96 or lower than -1.96, many cells of the contingency tables represent meaningful relationships (at the 5% significance level) between the three personas and the section or instructor. In other words, the way the instructors have employed Moodle in their sections affected the personas that their students represented.

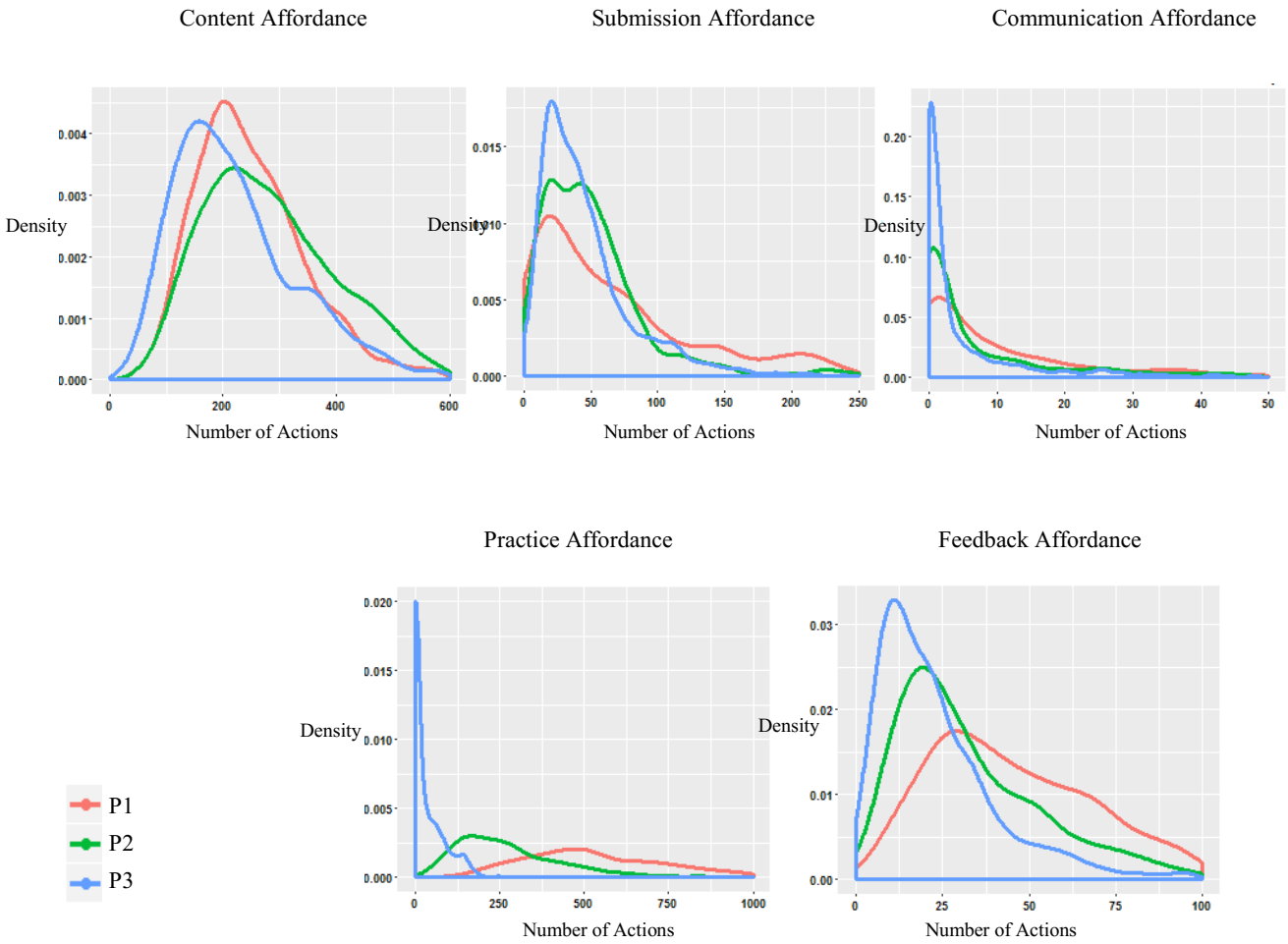

Figure 3-10-4. Personas distribution over actualization of each affordance using Kernel Density Estimation

Table 3-10-3. Contingency table for members of the three personas across sections

			Personas				Total
			Not-clustered	P1	P2	P3	
Section Code	F3260A	Count	4	56	25	6	91
		Expected Count	21.0	24.6	17.4	28.0	91.0
		% within Section	4.4%	61.5%	27.5%	6.6%	100.0%
		% within Personas	0.7%	8.6%	5.5%	0.8%	3.8%
		% of Total	0.2%	2.3%	1.0%	0.3%	3.8%
		Std. Residual	-3.7	6.3	1.8	-4.2	

	F3260C	Count	55	29	11	9	104
		Expected Count	24.0	28.2	19.9	31.9	104.0
		% within Section	52.9%	27.9%	10.6%	8.7%	100.0%
		% within Personas	10.0%	4.5%	2.4%	1.2%	4.3%
		% of Total	2.3%	1.2%	0.5%	0.4%	4.3%
		Std. Residual	6.3	.2	-2.0	-4.1	
	F326BB	Count	2	28	27	22	79
		Expected Count	18.2	21.4	15.1	24.3	79.0
		% within Section	2.5%	35.4%	34.2%	27.8%	100.0%
		% within Personas	0.4%	4.3%	5.9%	3.0%	3.3%
		% of Total	0.1%	1.2%	1.1%	0.9%	3.3%
		Std. Residual	-3.8	1.4	3.1	-.5	
	F5150C	Count	49	46	3	15	113
		Expected Count	26.1	30.6	21.6	34.7	113.0
		% within Section	43.4%	40.7%	2.7%	13.3%	100.0%
		% within Personas	8.9%	7.1%	0.7%	2.0%	4.7%
		% of Total	2.0%	1.9%	0.1%	0.6%	4.7%
		Std. Residual	4.5	2.8	-4.0	-3.3	
	F5150J	Count	51	34	12	17	114
		Expected Count	26.3	30.9	21.8	35.0	114.0
		% within Section	44.7%	29.8%	10.5%	14.9%	100.0%
		% within Personas	9.2%	5.2%	2.6%	2.3%	4.8%
		% of Total	2.1%	1.4%	0.5%	0.7%	4.8%
		Std. Residual	4.8	.6	-2.1	-3.0	
	F515AA	Count	64	24	7	15	110
		Expected Count	25.4	29.8	21.1	33.8	110.0
		% within Section	58.2%	21.8%	6.4%	13.6%	100.0%
		% within Personas	11.6%	3.7%	1.5%	2.0%	4.6%
		% of Total	2.7%	1.0%	0.3%	0.6%	4.6%
		Std. Residual	7.7	-1.1	-3.1	-3.2	
	F515BB	Count	69	25	9	21	124
		Expected Count	28.6	33.6	23.7	38.1	124.0
		% within Section	55.6%	20.2%	7.3%	16.9%	100.0%
		% within Personas	12.5%	3.9%	2.0%	2.9%	5.2%
		% of Total	2.9%	1.0%	0.4%	0.9%	5.2%
		Std. Residual	7.6	-1.5	-3.0	-2.8	
	F5250A	Count	2	26	27	46	101
		Expected Count	23.3	27.3	19.3	31.0	101.0
		% within Section	2.0%	25.7%	26.7%	45.5%	100.0%
		% within Personas	0.4%	4.0%	5.9%	6.3%	4.2%
		% of Total	0.1%	1.1%	1.1%	1.9%	4.2%

		Std. Residual	-4.4	-.3	1.7	2.7	
	F5250B	Count	4	19	34	52	109
		Expected Count	25.1	29.5	20.9	33.5	109.0
		% within Section	3.7%	17.4%	31.2%	47.7%	100.0%
		% within Personas	0.7%	2.9%	7.4%	7.1%	4.6%
		% of Total	0.2%	0.8%	1.4%	2.2%	4.6%
		Std. Residual	-4.2	-1.9	2.9	3.2	
	F5250C	Count	7	18	37	51	113
		Expected Count	26.1	30.6	21.6	34.7	113.0
		% within Section	6.2%	15.9%	32.7%	45.1%	100.0%
		% within Personas	1.3%	2.8%	8.1%	6.9%	4.7%
		% of Total	0.3%	0.8%	1.5%	2.1%	4.7%
		Std. Residual	-3.7	-2.3	3.3	2.8	
	F5250D	Count	4	23	44	44	115
		Expected Count	26.5	31.1	22.0	35.3	115.0
		% within Section	3.5%	20.0%	38.3%	38.3%	100.0%
		% within Personas	0.7%	3.5%	9.6%	6.0%	4.8%
		% of Total	0.2%	1.0%	1.8%	1.8%	4.8%
		Std. Residual	-4.4	-1.5	4.7	1.5	
	F5250E	Count	5	30	33	46	114
		Expected Count	26.3	30.9	21.8	35.0	114.0
		% within Section	4.4%	26.3%	28.9%	40.4%	100.0%
		% within Personas	0.9%	4.6%	7.2%	6.3%	4.8%
		% of Total	0.2%	1.3%	1.4%	1.9%	4.8%
		Std. Residual	-4.2	-.2	2.4	1.9	
	F525BB	Count	7	21	19	48	95
		Expected Count	21.9	25.7	18.2	29.2	95.0
		% within Section	7.4%	22.1%	20.0%	50.5%	100.0%
		% within Personas	1.3%	3.2%	4.1%	6.5%	4.0%
		% of Total	0.3%	0.9%	0.8%	2.0%	4.0%
		Std. Residual	-3.2	-.9	.2	3.5	
	F5260A	Count	4	28	30	48	110
		Expected Count	25.4	29.8	21.1	33.8	110.0
		% within Section	3.6%	25.5%	27.3%	43.6%	100.0%
		% within Personas	0.7%	4.3%	6.6%	6.5%	4.6%
		% of Total	0.2%	1.2%	1.3%	2.0%	4.6%
		Std. Residual	-4.2	-.3	1.9	2.4	
	F5260B	Count	0	44	21	51	116
		Expected Count	26.8	31.4	22.2	35.6	116.0
		% within Section	0.0%	37.9%	18.1%	44.0%	100.0%
		% within Personas	0.0%	6.8%	4.6%	6.9%	4.8%

		% of Total	0.0%	1.8%	0.9%	2.1%	4.8%
		Std. Residual	-5.2	2.2	-.3	2.6	
	F5260C	Count	3	15	16	79	113
		Expected Count	26.1	30.6	21.6	34.7	113.0
		% within Section	2.7%	13.3%	14.2%	69.9%	100.0%
		% within Personas	0.5%	2.3%	3.5%	10.7%	4.7%
		% of Total	0.1%	0.6%	0.7%	3.3%	4.7%
		Std. Residual	-4.5	-2.8	-1.2	7.5	
	F526AA	Count	2	42	30	34	108
		Expected Count	24.9	29.2	20.7	33.2	108.0
		% within Section	1.9%	38.9%	27.8%	31.5%	100.0%
		% within Personas	0.4%	6.5%	6.6%	4.6%	4.5%
		% of Total	0.1%	1.8%	1.3%	1.4%	4.5%
		Std. Residual	-4.6	2.4	2.1	.1	
	F526BB	Count	1	7	13	67	88
		Expected Count	20.3	23.8	16.8	27.0	88.0
		% within Section	1.1%	8.0%	14.8%	76.1%	100.0%
		% within Personas	0.2%	1.1%	2.8%	9.1%	3.7%
		% of Total	0.0%	0.3%	0.5%	2.8%	3.7%
		Std. Residual	-4.3	-3.4	-.9	7.7	
	W4260D	Count	8	33	21	35	97
		Expected Count	22.4	26.3	18.6	29.8	97.0
		% within Section	8.2%	34.0%	21.6%	36.1%	100.0%
		% within Personas	1.4%	5.1%	4.6%	4.8%	4.1%
		% of Total	0.3%	1.4%	0.9%	1.5%	4.1%
		Std. Residual	-3.0	1.3	.6	1.0	
	W4260G	Count	43	40	19	15	117
		Expected Count	27.0	31.7	22.4	35.9	117.0
		% within Section	36.8%	34.2%	16.2%	12.8%	100.0%
		% within Personas	7.8%	6.2%	4.1%	2.0%	4.9%
		% of Total	1.8%	1.7%	0.8%	0.6%	4.9%
		Std. Residual	3.1	1.5	-.7	-3.5	
	W526CC	Count	85	25	3	3	116
		Expected Count	26.8	31.4	22.2	35.6	116.0
		% within Section	73.3%	21.6%	2.6%	2.6%	100.0%
		% within Personas	15.4%	3.9%	0.7%	0.4%	4.8%
		% of Total	3.6%	1.0%	0.1%	0.1%	4.8%
		Std. Residual	11.3	-1.1	-4.1	-5.5	
	W526DD	Count	83	16	6	6	111
		Expected Count	25.6	30.1	21.2	34.1	111.0
		% within Section	74.8%	14.4%	5.4%	5.4%	100.0%

		% within Personas	15.0%	2.5%	1.3%	0.8%	4.6%
		% of Total	3.5%	0.7%	0.3%	0.3%	4.6%
		Std. Residual	11.3	-2.6	-3.3	-4.8	
	W526EE	Count	0	19	11	5	35
		Expected Count	8.1	9.5	6.7	10.8	35.0
		% within Section	0.0%	54.3%	31.4%	14.3%	100.0%
		% within Personas	0.0%	2.9%	2.4%	0.7%	1.5%
		% of Total	0.0%	0.8%	0.5%	0.2%	1.5%
		Std. Residual	-2.8	3.1	1.7	-1.8	
Total		Count	552	648	458	735	2393
		Expected Count	552.0	648.0	458.0	735.0	2393.0
		% within Section	23.1%	27.1%	19.1%	30.7%	100.0%
		% within Personas	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	23.1%	27.1%	19.1%	30.7%	100.0%

Table 3-10-4. Contingency table for members of the three personas across instructors

			Personas				**Total**
			Not Clustered	**P1**	**P2**	**P3**	
Instructor Code	INS1	Count	12	51	52	94	209
		Expected Count	48.2	56.6	40.0	64.2	209.0
		% within Instructor	5.7%	24.4%	24.9%	45.0%	100.0%
		% within Personas	2.2%	7.9%	11.4%	12.8%	8.7%
		% of Total	0.5%	2.1%	2.2%	3.9%	8.7%
		Std. Residual	-5.2	-.7	1.9	3.7	
	INS2	Count	15	60	115	147	337
		Expected Count	77.7	91.3	64.5	103.5	337.0
		% within Instructor	4.5%	17.8%	34.1%	43.6%	100.0%
		% within Personas	2.7%	9.3%	25.1%	20.0%	14.1%
		% of Total	0.6%	2.5%	4.8%	6.1%	14.1%
		Std. Residual	-7.1	-3.3	6.3	4.3	
	INS3	Count	3	15	16	79	113
		Expected Count	26.1	30.6	21.6	34.7	113.0
		% within Instructor	2.7%	13.3%	14.2%	69.9%	100.0%
		% within Personas	0.5%	2.3%	3.5%	10.7%	4.7%
		% of Total	0.1%	0.6%	0.7%	3.3%	4.7%
		Std. Residual	-4.5	-2.8	-1.2	7.5	
	INS4	Count	4	28	30	48	110
		Expected Count	25.4	29.8	21.1	33.8	110.0
		% within Instructor	3.6%	25.5%	27.3%	43.6%	100.0%
		% within Personas	0.7%	4.3%	6.6%	6.5%	4.6%

		% of Total	0.2%	1.2%	1.3%	2.0%	4.6%
		Std. Residual	-4.2	-.3	1.9	2.4	
	INS5	Count	2	26	27	46	101
		Expected Count	23.3	27.3	19.3	31.0	101.0
		% within Instructor	2.0%	25.7%	26.7%	45.5%	100.0%
		% within Personas	0.4%	4.0%	5.9%	6.3%	4.2%
		% of Total	0.1%	1.1%	1.1%	1.9%	4.2%
		Std. Residual	-4.4	-.3	1.7	2.7	
	INS6	Count	1	7	13	67	88
		Expected Count	20.3	23.8	16.8	27.0	88.0
		% within Instructor	1.1%	8.0%	14.8%	76.1%	100.0%
		% within Personas	0.2%	1.1%	2.8%	9.1%	3.7%
		% of Total	0.0%	0.3%	0.5%	2.8%	3.7%
		Std. Residual	-4.3	-3.4	-.9	7.7	
	INS7	Count	280	290	144	152	866
		Expected Count	199.8	234.5	165.7	266.0	866.0
		% within Instructor	32.3%	33.5%	16.6%	17.6%	100.0%
		% within Personas	50.7%	44.8%	31.4%	20.7%	36.2%
		% of Total	11.7%	12.1%	6.0%	6.4%	36.2%
		Std. Residual	5.7	3.6	-1.7	-7.0	
	INS8	Count	2	42	30	34	108
		Expected Count	24.9	29.2	20.7	33.2	108.0
		% within Instructor	1.9%	38.9%	27.8%	31.5%	100.0%
		% within Personas	0.4%	6.5%	6.6%	4.6%	4.5%
		% of Total	0.1%	1.8%	1.3%	1.4%	4.5%
		Std. Residual	-4.6	2.4	2.1	.1	
	INS9	Count	233	129	31	68	461
		Expected Count	106.3	124.8	88.2	141.6	461.0
		% within Instructor	50.5%	28.0%	6.7%	14.8%	100.0%
		% within Personas	42.2%	19.9%	6.8%	9.3%	19.3%
		% of Total	9.7%	5.4%	1.3%	2.8%	19.3%
		Std. Residual	12.3	.4	-6.1	-6.2	
Total		Count	552	648	458	735	2393
		Expected Count	552.0	648.0	458.0	735.0	2393.0
		% within Instructor	23.1%	27.1%	19.1%	30.7%	100.0%
		% within Personas	100.0%	100.0 %	100.0%	100.0%	100.0%
		% of Total	23.1%	27.1%	19.1%	30.7%	100.0%