PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

THE EMERGENCE OF OPERATIVE KNOWLEDGE

RENATO VERDUGO

Thesis submitted to the Office of Research and Graduate Studies in partial fulfillment of the requirements for the Degree of Doctor in Engineering Sciences.

Advisor:
MIGUEL NUSSBAUM

Santiago de Chile, August, 2013

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To Lida, Renato, Javiera, Andrés, Miguel and Miryam.

ACKNOWLEDGMENTS

None of this would have been possible if it wasn't for Miguel. During these years I've found in you a guide and a friend. *Thank you!*

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I thank my family –Lida, Renato, Javiera and Andrés- for supporting me every step of the way. I have been blessed with many friends –you know who you are!- who have been a permanent source of encouragement, great advice and awesome fun. *Thanks to all of you!*

I owe many of the ideas in this thesis to the insightful conversations and the friendly advice I've recieved from Miryam and Pablo. *Thanks!*

Finally, I would like to thank Angela (Kew, Royal Botanic Gardens), Julie (SRI International) and Vera (SRI International) for allowing me to apply the ideas from this thesis to real life problems. *Thanks for the invaluable experience of working with you!*

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RENATO VERDUGO

RESUMEN

La tecnología nos provee acceso permanente y ubicuo a repositorios en línea de la experiencia humana, cambiando la forma en la que nos relacionamos con la información y el conocimiento. El almacenamiento y la recuperación de información en la era pre-digital –basado en objetos físicos- forzaba un indexamiento lineal y unívoco, estableciendo por tanto mecanismos fijos de organización, validación y circulación de objetos mediales – dominados por el texto impreso. El ecosistema medial de nuestros días ha reestructurado las lógicas bajo las cuales clasificamos y accedemos contenido, estableciendo bibliotecas recentrables donde la curatoría y la linealidad son remplazadas por el poder computacional de las palabras clave y los motores de búsqueda. La base de la revolución de la información y comunicación que vivimos hoy día es la posibilidad de construir cadenas de documentos personalizadas a través de las capacidades del hipervínculo.

El Conocimiento Operativo -concepto que se establece y define por primera vez en esta tesis- son pequeñas fracciones de conocimiento que pueden ser accedidas de forma veloz y sencilla, que permiten a los individuos consumir, crear y transformar ideas a través de dominios disciplinares, incluso sin ser expertos. Esta tesis plantea un recorrido bibliográfico a través de los orígenes del fenómeno del Conocmiento Operativo; desde tópicos socio-culturales -como lo son las concepciones de individuo, comunidad y cultura-, pasando por las raíces y precedentes técnicos que posibilitan acceso ubicuo y permanente a repostiorios virtuales, hasta el impacto futuro de este fenómeno.

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Miembros de la Comisión de Tesis Doctoral

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Angela McFarlane
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Santiago, Agosto, 2013

PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
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ABSTRACT

Technology provides us with ubiquitous and permanent access to an online repository of human experience, changing the way we relate to information and knowledge. Pre-digital storage and retrieval –based on physical objects- forced lineal and univocal indexing, thus establishing fixed mechanisms for organization, validation and circulation of medial objects –dominated by print text. Today's medial landscape has restructured the logics under which we classify and access content, establishing recenterable libraries where curatorship and linearity are replaced by the computational power of queries and search engines. The base of today's information and communication revolution is the possibility of building 'on-demand' chains of documents through hyperlinking capabilities.

Operative Knowledge –a concept that is established and defined for the first time by this thesis- are small fractions of knowledge, which can be quickly and easily accessed, that allow individuals to consume, create and transform ideas across disciplinary boundaries, even if they are not experts. This thesis proposes a bibliographical journey through the origins of the Operative Knowledge phenomenon; from socio-cultural topics –like the conceptions of individual, community and culture-, to the technical developments that enable ubiquitous and permanent access to virtual repositories, and finally, the future impact of this phenomenon.

This thesis had the support of the Center for Research on Educational Policy and Practice, Grant CIE01- CONICYT and '*CONICYT Beca para Estudios de Doctorado en Chile'*

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THE EMERGENCE OF OPERATIVE KNOWLEDGE

37 ideas to conceptualize the ways in which technology
has re-written our relationship with knowledge

RENATO VERDUGO

This thesis is based on the following papers, referred to in the text by their Roman numerals.

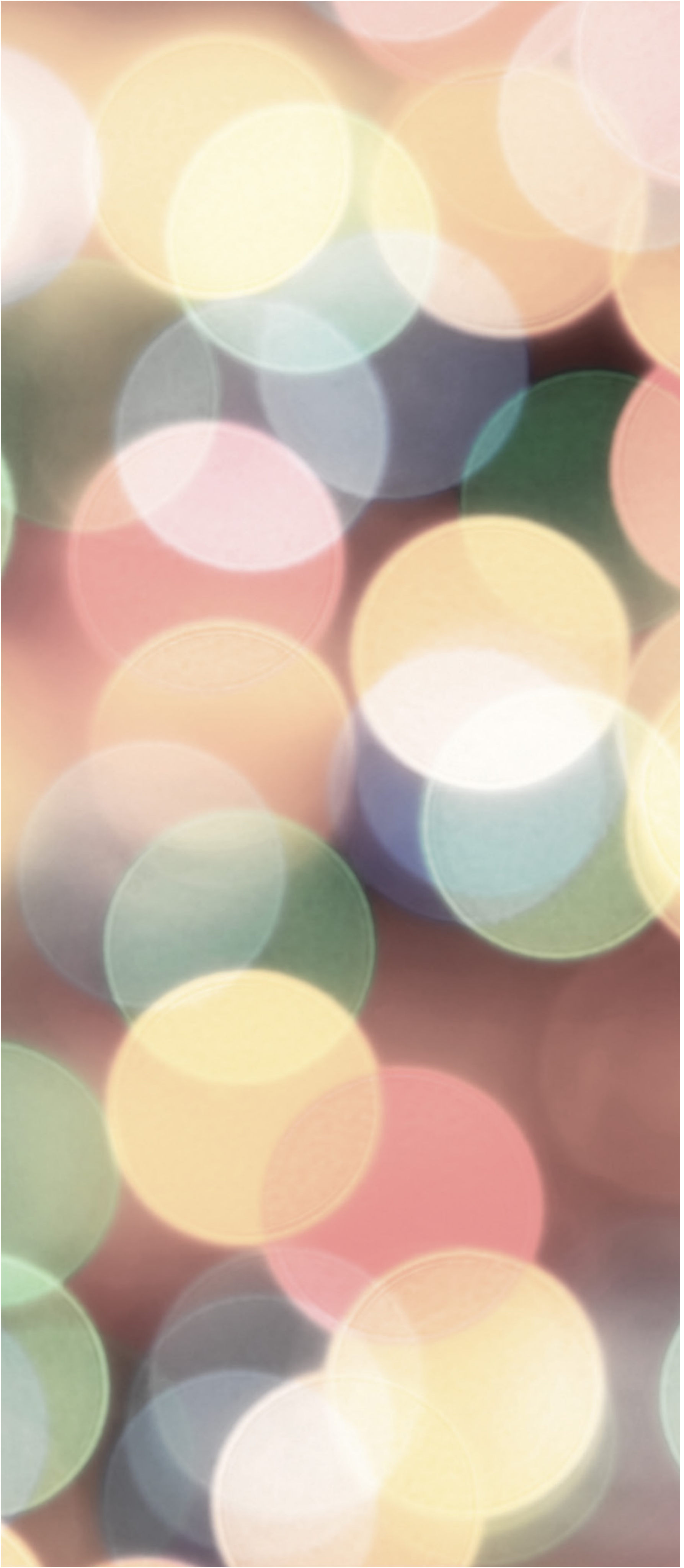
PAPER I: Verdugo, R., Nussbaum, M., Claro, M., Sepúlveda, M., Esobar, B., Rendich, R. & Riveros, F. (2013). Preparing Undergraduate Computer Science Students to Face Intercultural and Multidisciplinary Scenarios. *IEEE Transactions on Professional Communication*, 56(1), 67-80.

PAPER II: Verdugo, R., Barros, L., Albornoz, D., Nussbaum, M. & McFarlane, A. Scripting For Collaborative Search Computer–Supported Classroom Activities.

PAPER III: Verdugo, R., Nussbaum, M., Corro, P., Nuñez, P., & Navarrete, P. (2011). Interactive films and coconstruction. *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMCCAP)*, 7(4), 39.

PAPER IV: Verdugo, R., McFarlane, A. & Nussbaum, M. Digital access to interpretation information at the Royal Botanic Gardens, Kew: the “smartphone wall”.

Preface



Interdisciplinary computer science

Disciplinary structures provide order to a group of fields related to knowledge that would otherwise seem unapproachable because of a lack of organization. Universities as an idea –which, from their etymology, present themselves as the universal that does not allow division- when facing their mission-ambition of being the great intellectual center of human experience, resort to invented cartographies of knowledge from which they can raise scaffolding previous to their educational, research and extension missions. Through this, each university determines not only its administrative logic, but also its work interactions and the products that will emerge from it. This is the origin of an efficient way of managing highly complex institutions, by slicing their functions into a series of parallel sub-institutions that –despite acting independently- share a common mission. This shapes within each university a division of human knowledge into a series of highly delimited disciplines, with univocal logics of belonging and not belonging.

Disciplines have enabled thorough vertical knowledge –specialization-, but have sacrificed the possibility of a horizontal development where areas of applicability interconnect. Disciplinary specificity presents itself in the opposite direction of creativity by subjecting individuals to an arbitrary and restrictive framework. Disciplines are political and managerial shortcuts, not organic structures of thought, and therefore constitute external and subjective limitations; transgression and defiance of its frontiers situates human intellect above specialization and indoctrination conventions. Interdisciplinary work quests for a convergence of knowledge. Through interdisciplinary resistance, academic dogma disappears and a unified body that transcends the political dimensions of knowledge emerges.

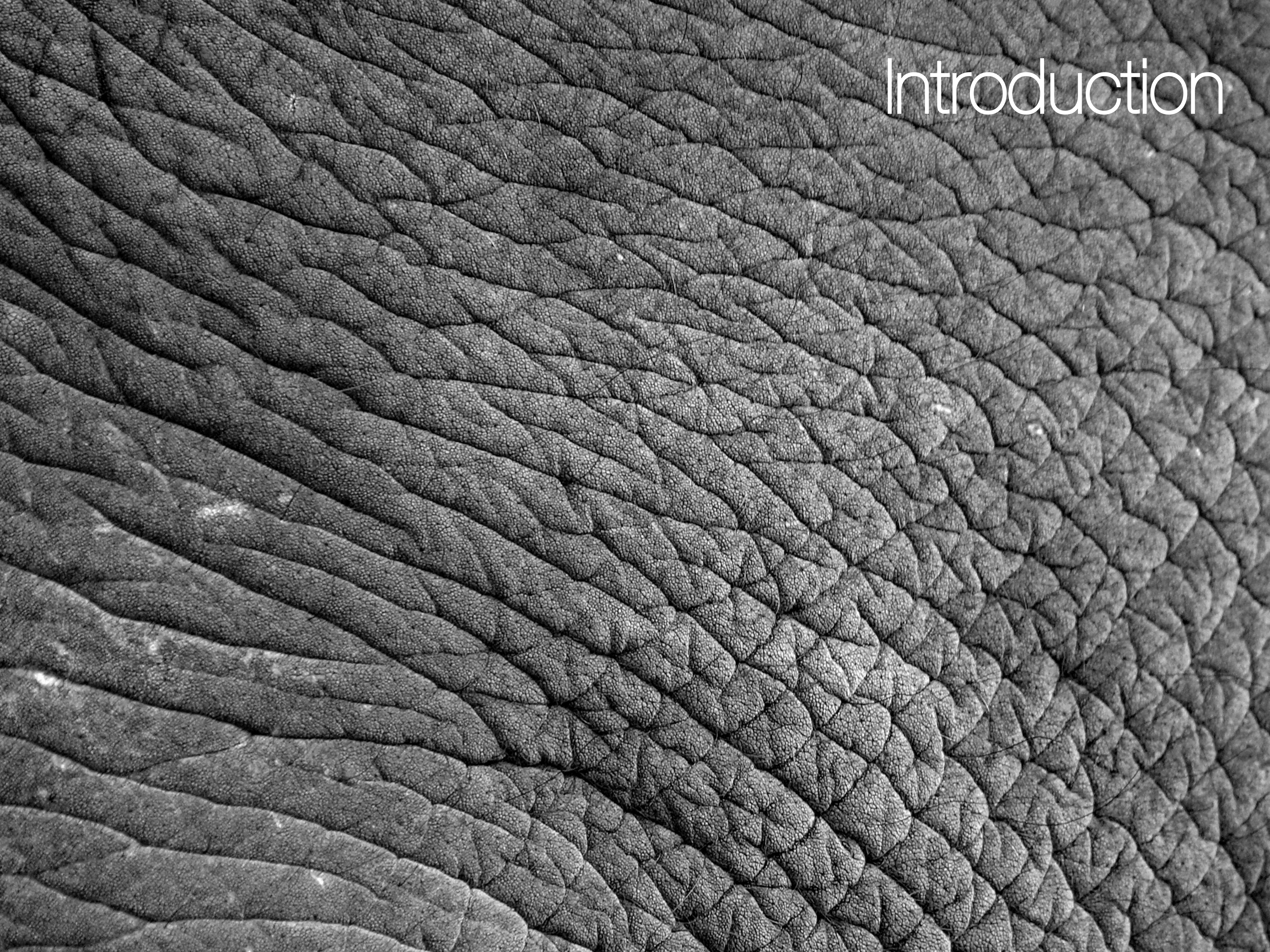
Interdisciplinary work appears in the frontier between bodies of knowledge, and pretends that the division between them does not exist. Rigid academic structure –and its consequent extension to professional fields, disciplinary practice and, ultimately, into everyday life- has raised walls that render the documents, techniques and problems of a discipline inaccessible from its exterior. The work to be done consists precisely of challenging the founding order and tensioning the boundary conditions that delimit a discipline's domain of action.

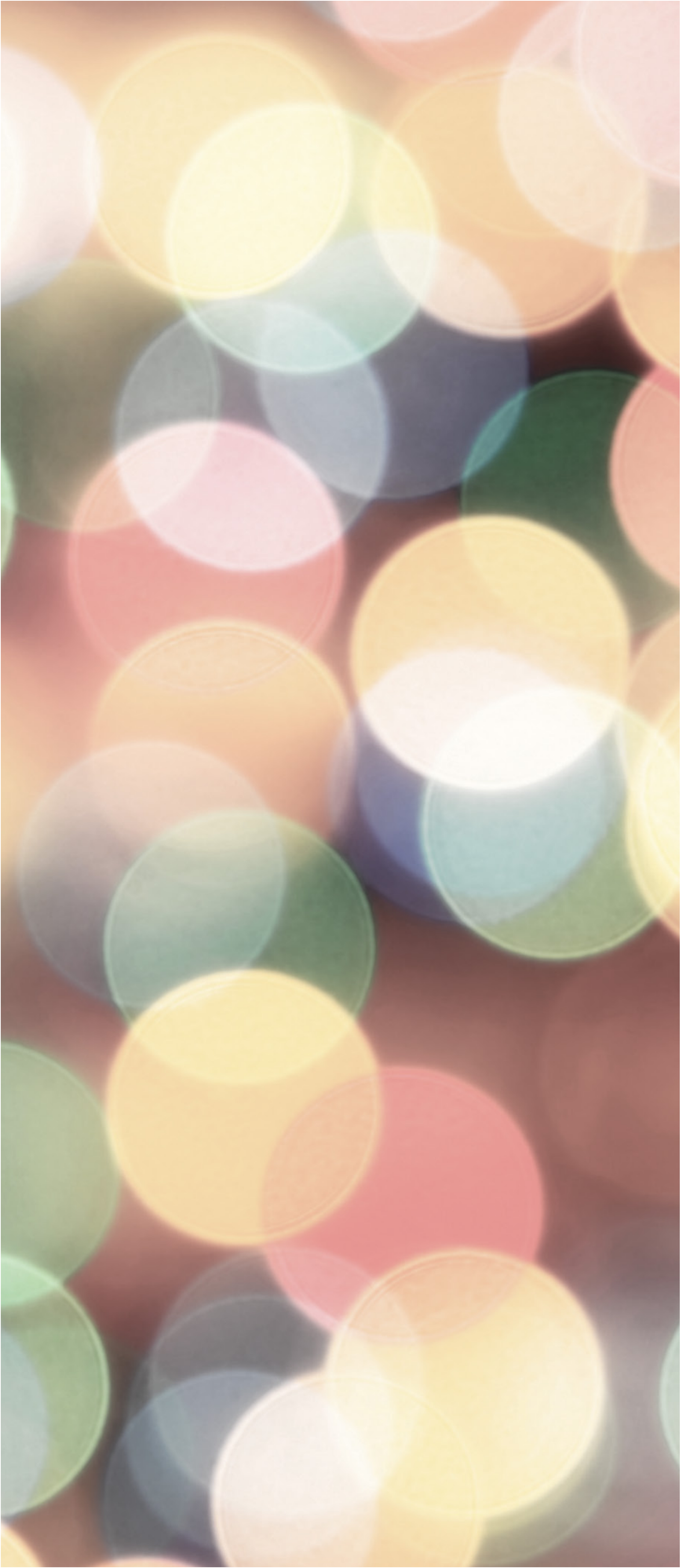
Computer science is a broad label encompassing a wide and ever-expanding range of fields. User-centered design and technology deployment magnifies its scope by situating technical developments within particular contexts and weighting in human factors. Analyzing computers, technology and informatics revolutions not only as technical transformations, but also as agents of cultural, social and political reform, enables vast opportunity for interdisciplinary constructions. Mark Weiser –who described the founding principles behind ubiquitous computing-, when explaining the origins of his work, portrayed it as "thinking less about particular features of a computer –such as random access memory and number of pixels or megahertz- and much more about the detailed situational use of the technology. In particular, how were computers embedded within the complex social framework of daily activity, and how did they interplay with the rest of our densely woven physical environment (also known as "the real world")?" (Weiser, Gold & Brown 1999). This thesis follows a similar predicament; although it is rooted in computer science it poses questions that transcend its realm. It draws from a series of disjointed fields –defying traditional affiliations- to present itself as a patchwork of questions, references and answers without a unique domain of disciplinary validation.

Understanding technology as contextually situated –therefore envisioning it as interconnected with an environment to which it serves a purpose- requires modeling the interaction under which technical development becomes a component of human activity and experience (**Paper I**). As explained by Genevieve Bell and Paul Dourish, "computational technologies are embedded in social structures and cultural scripts of many sorts; ubicomp [ubiquitous computing] technologies prove also to be sites of social engagement, generational conflict, domestic regulation, religious practice, state surveillance, civic protest, romantic encounters, office politics, artistic expression, and more. What this suggests is that we need a deeper understanding of how social and cultural practice is carried out in and around emerging information technologies" (Dourish & Bell, 2011).

Belief systems –political, social, religious, philosophical, technical, or others- are informed by individuals' understanding of their specific contextual scenarios. Any attempt to present a modeling of socio-cultural interactions, along with its underlying value system, must address and embrace its major limitation: subjectivity. No single model attempting to explain technology and its interaction with society will stand out as the sole carrier of truth; attempting to build such a model would be naïve at best, an authoritarian manifesto at worst. Because of this, previous to the work being presented in this document, the notion and understanding of a hypothesis must be established. Under a traditional scientific conception, a hypothesis is "a tentative assumption made in order to draw out and test its logical or empirical consequences" (Merriam-Webster Online); yet this understanding implies that any conclusions drawn from it will have some form of unquestionable transversal validity –a reliable expectation of replicability. Belief systems cannot base their postulates on empirical assertion; they must draw their findings from a sensemaking process that one can share with others as persuasive argumentation, but embracement and endorsement will ultimately depend on the receptor. In this sense, a hypothesis is better understood as "an assumption or concession made for the sake of argument" (Merriam-Webster Online). Adhering to this understanding of hypothesis, this thesis is not about building universally valid theorems that belong to specific disciplinary domains. I wish to contribute to a 'multiversal' understanding of the impact and consequences that the products that emerge from computer science have over culture and society. The proposed hypotheses must then be understood as mission statements for the quest of understanding a world with ubiquitous hyperlinking abilities. No pre-made disciplinary cartography serves this purpose; the argumentation will draw from various sources, following a custom made map of human knowledge.

Introduction





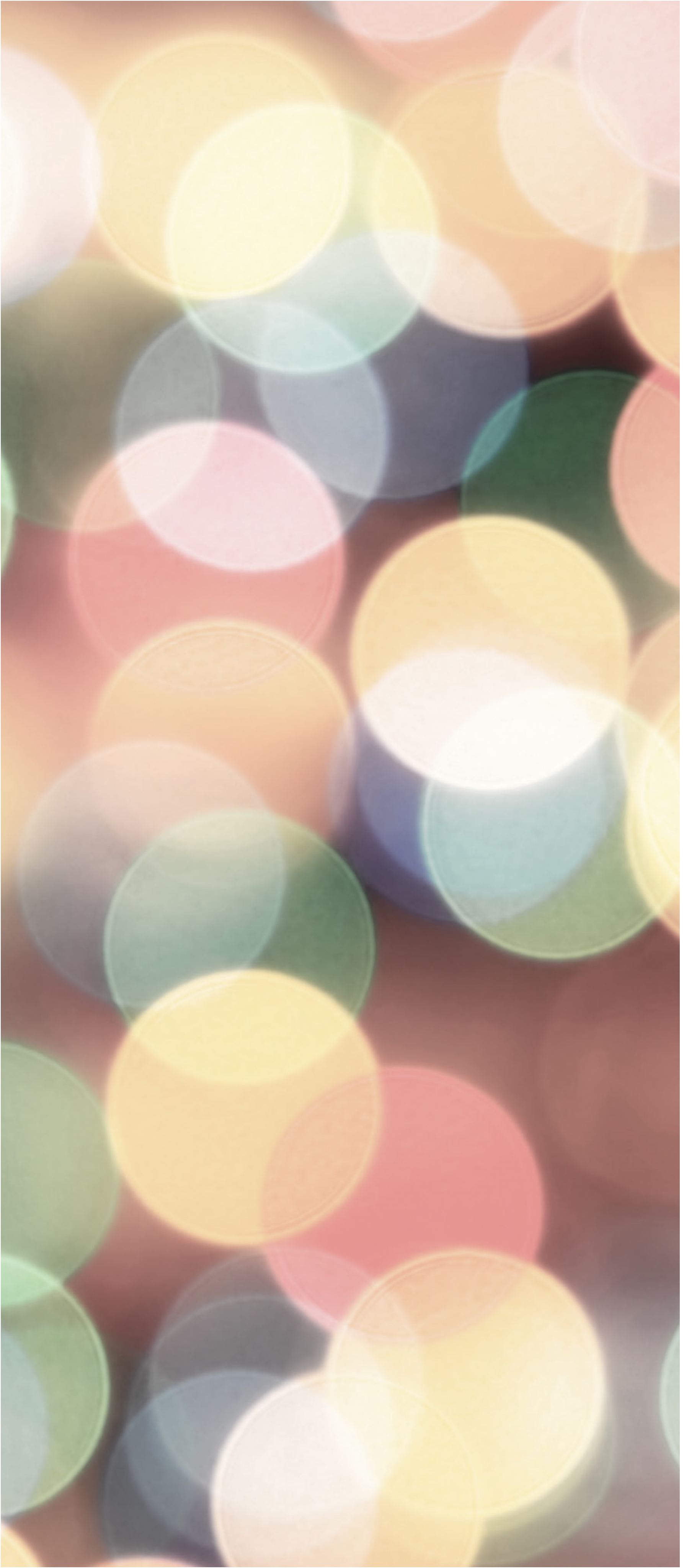
Between two popes

Today we face a technological mediation of knowledge whose scope and magnitude is only comparable to the advent of writing and the invention of the printing press (Cox, 2000; Hobart & Schiffman, 2000). This doctoral dissertation is an initial attempt to provide theoretical underpinnings to this phenomenon, and I therefore must open this work by acknowledging the undeniable fact that as I write, I cannot avoid the short-sightedness that comes with chronological proximity to a revolution that continues to unfold and mutate daily. I offer this work as an open draft, a non-definite answer to questions that will continue to evolve as technology keeps blazing trails into new frontiers, and human experience and knowledge continue to be shaped by the devices that have quickly populated every inch, every second, every bit of our life.

By way of introduction, I will use a fortuitous example that illustrates the strength of the phenomenon I wish to describe. Two historical events that have nothing to do with technology -quite the contrary, they relate to the traditions and survival of a millenary institution- give us a window into the proliferation of the ubiquitous technologies that are rewriting, today, our relation with knowledge. On April 19th 2005, catholic parishioners gathered in Vatican City to witness the announcement of the new pope, H.H. Pope Benedict XVI, and to listen to his first *Urbi et Orbi* blessing. On March 13th, 2013 the world witnessed the same ritual for the thirty-fifth time, now for the announcement of H.H. Pope Francis. Multiple press photographies have documented these two events, some of which show the crowds gathered outside of St. Peter's Basilica. If we compare both groups (Figure 1), a shift in the way that people experiment and witness such a historic event becomes apparent. The passive contemplation of 2005 has given way to a massive presence of mobile devices, and through them an active documentation of the event. We can assume, without fear of being wrong, that the presence of these devices comes along with invisible transmission networks from which physical presence in St. Peter's Square is paired with virtual dialogues that connect this specific coordinate of the space-time duality with an infinite network of interactions throughout the world.

Figure 1: Exterior of St. Peter's Basilica, April 19th, 2005 (above) and March 13th, 2013 (below). (Source: http://instagram.com/p/W2BuMLQLRB/)

Context



From 1945 to hypermedia

The eight years anecdotally illustrated by Benedict XVI's papacy are the most recent chapter of a phenomenon with its roots in 1945, the year in which Vannevar Bush –then director of the United States Office of Scientific Research and Development-, facing the soon to come end of World War II published the essay "As We May Think", where he attempted to envision what scientists should do as soon as military challenges halted and science could return to its non-war related research. In it, he describes the increasing complexity of the information scenario by noting that "science has provided the swiftest communication between individuals; it has provided a record of ideas and has enabled man to manipulate and to make extracts from that record so that knowledge evolves and endures throughout the life of a race rather than that of an individual. There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers - conclusions which he cannot find time to grasp, much less to remember, as they appear. Yet specialization becomes increasingly necessary for progress, and the effort to bridge between disciplines is correspondingly superficial. Professionally our methods for transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose" (Bush, 1945). Bush explains the impossibility of consuming knowledge as quickly as it is produced and explains that, "our ineptitude in getting at the record is largely caused by the artificiality of systems of indexing. When data of any sort are placed in storage, they are filed alphabetically or numerically, and information is found (when it is) by tracing it down from subclass to subclass. It can be in only one place, unless duplicates are used; one has to have rules as to which path will locate it, and the rules are cumbersome. Having found one item, moreover, one has to emerge from the system and re-enter on a new path" (Bush, 1945). Faced with this problem he continues to explain how the human mind works differently by operating by association, snapping from one element to the next through freely linking, without the constraints of an indexing system. He envisions a future technological development –which he calls a 'memex'- that could artificially replicate the associating powers of the human brain. Said device would enable people to build 'trails' interconnecting separate items, thus tying them together. Through this, "wholly new forms of encyclopedias will appear –he explained-, ready-made with a mesh of associative trails running through them" (Bush, 1945).

Today, Bush's essay is considered by many authors as the first approach into what we now call hypertext and hypermedia (Irish & Trigg, 1989; Landow, 2006; Stover, 1989; Whitehead, 2000). Ted Nelson coined both terms in 1965 (Nelson, 1965), and since then hyperlinking capabilities, along with the technological possibility of instant retrieval, have restructured the way we relate to humanity's interwoven knowledge network.

The use of physical substrates for documentation and registry –namely, print material and non-digital resources-, as with any other technology, implies the acceptance of its 'program'; because of the fact that prior to the emergence of the Internet, information was documented mainly through written, and later printed, words, the hegemonic dominance of books composed a model of hierarchical and linear consumption of text (De Bra, 2002). The prohibitive cost of print text encouraged the formation of validation circuits where notions of center and margin followed economic principles. Today, virtual networks and their almost unlimited storage capacity replace the need for physical resources, enabling an opening of the registry. New logics for media consumption are therefore required, referring to information sorting, retrieval, and non-linear reading. "As readers move through a web or network of texts, they continually shift the center –and hence the focus or organizing principle- of their investigation and experience. Hypertext, in other words, provides an infinitely recenterable system whose provisional point of focus depends on the reader, who becomes a truly active reader" (Landow, 2006).

Through hypertext and hypermedia's structure, paths connecting one document to the next transform the reading experience. "Scholarly articles situate themselves within a field of relations, most of which the print medium keeps out of sight and relatively difficult to follow because in print technology the referenced (or linked) materials lie spatially distant from the references to them. Electronic hypertext, in contrast, makes individual references easy to follow and the entire field of interconnections obvious and easy to navigate. Changing the ease with which one can orient oneself within such a context and pursue individual references radically changes the experience of reading and ultimately the nature of that which is read" (Landow, 2006). Pre-digital technology manifests a discontinuity between the results and creations of separate cognitive efforts. Under its regime, every book, every article and every object exists as an individual and isolated being – linked with the world only by its weak referencing and relying on a third person being willing to invest the time and resources required for intertextuality to occur. Hypertext and hypermedia present the cumulative creations of human ingenuity as a continuum and unified body of information. The mobile devices we carry with us everywhere we go –from the grocery store to historical events, like the announcement of the next pope- give us a permanent and ubiquitous channel of communication with the online repositories that are reshaping our relation with knowledge and human experience.

The path towards 37 ideas

The years 2005 and 2013 (Figure 1) coincide with my first year of undergraduate studies and my last year of doctoral work, respectively. It has been during this time window that I have conducted the work that shapes this thesis -first as an undergraduate researcher, then as part of the masters in computer science program and, finally, as part of my doctoral research. The postulates that constitute the theoretical body of this thesis are the result of the several research projects and academic work that I have participated in with Professor Miguel Nussbaum, at the School of Engineering at Pontificia Universidad Católica de Chile.

The goal of this thesis is to conceptualize the ways in which ubiquitous access to hypermedia realities have restructured our relation with knowledge. The initial hypothesis is that ubiquitous and permanent availability of hypermedia systems and registries are the seminal base for today's communication and information revolution; by transforming the objects we interact with, hyperlinks have changed the ways in which we conceive knowledge. The starting point for the theoretical constructions supporting this hypothesis are the following postulates, which come from the empirical projects that form the hands-on and applied basis of this thesis:

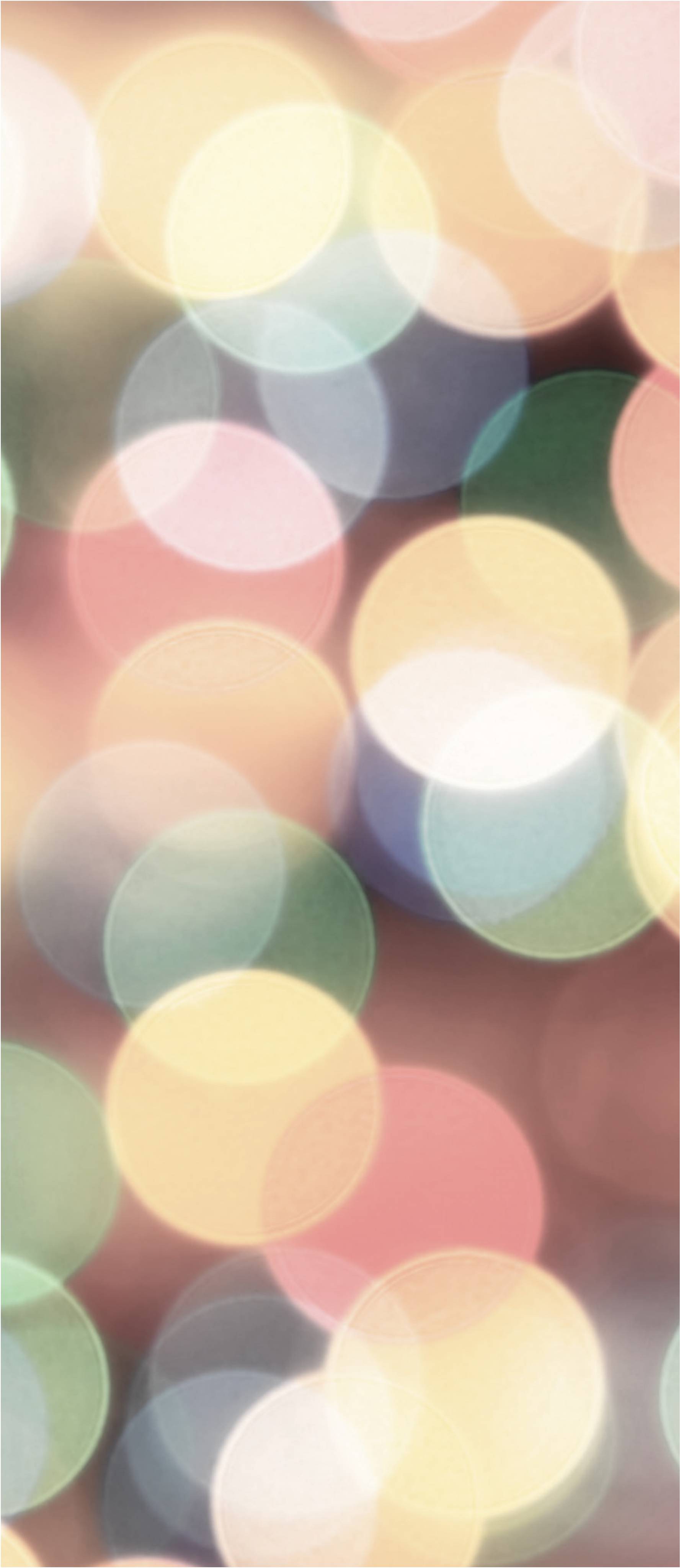
- Technology cannot exist isolated from its cultural contexts and the interdisciplinary crossroads in which its users cohabit (**Paper I**).
- Knowledge is built through the interaction of ideas that come from diverse origins, and this process is enriched through communication and collaboration between individuals (**Paper II**).
- Knowledge is an open body that only acquires meaning and purpose through an individual, within a specific context that instantiates its reception (**Paper III**).


37 ideas

"The composition of vast books is a laborious and impoverishing extravagance; to go on for five hundred pages developing an idea whose perfect oral exposition is possible in a few minutes. A better course of procedure is to pretend that these books already exist, and then to offer a summary, a commentary. (…) More reasonable, more inept, more indolent, I have preferred to write notes upon imaginary books."

Jorge Luis Borges

Prologue to "The garden of forking paths" (1941)



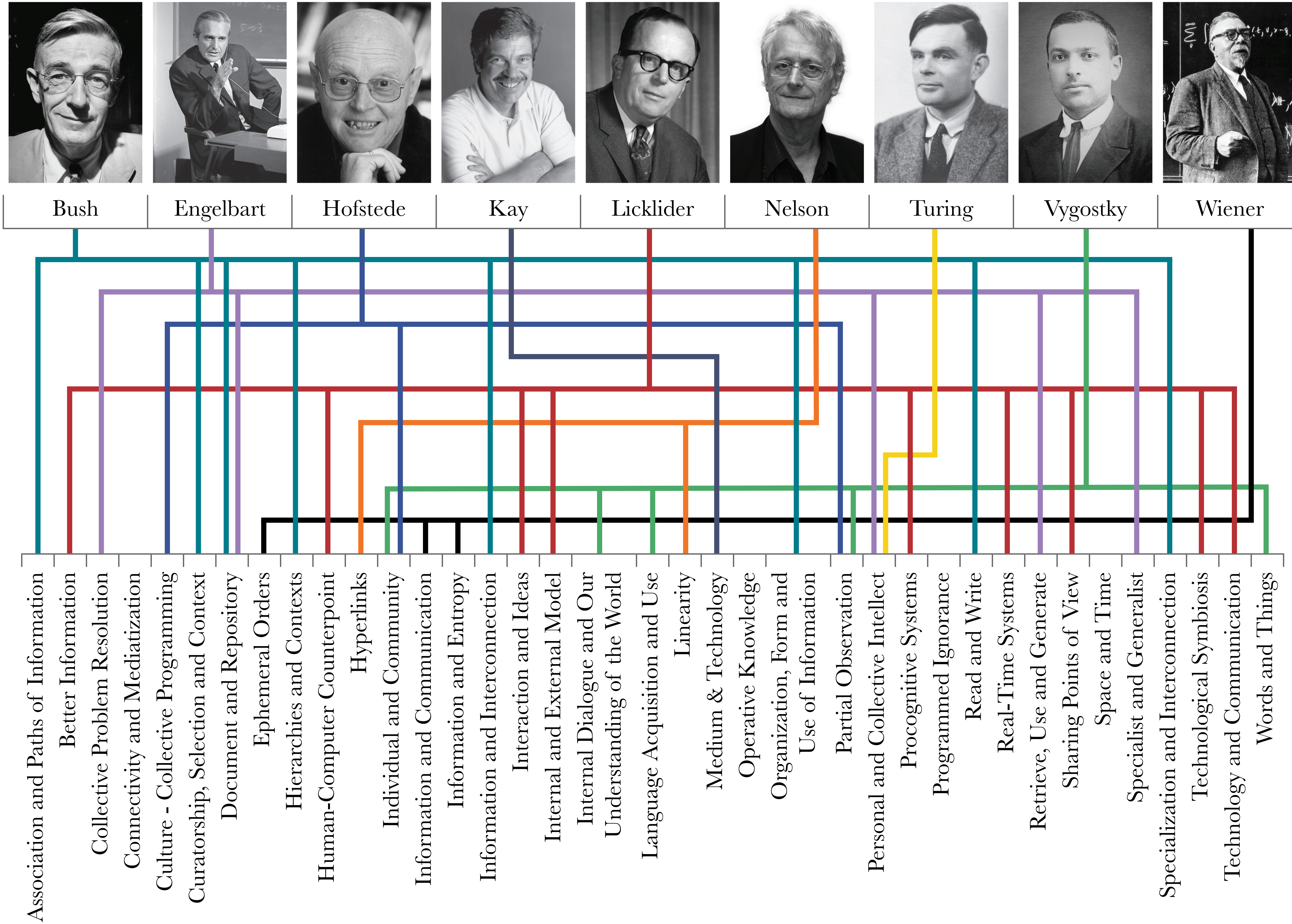
The emergence of operative knowledge

Facing an empty page and a blinking cursor provides ideas with a paralyzing freedom, and it is before this emptiness-induced reflection that creativity can find itself on paths towards uncharted territories. While looking for a method to document this thesis, I decided to follow Borges' advice, to imagine that it already existed -as if narrated by others- and to then find within that imaginary space the fundamental nucleus of its ideas. Through this methodology, the theoretical body this thesis contributes is composed of 37 ideas -that manifest themselves through text and image- that autonomously propose 37 reflections around the technological mediation of knowledge.

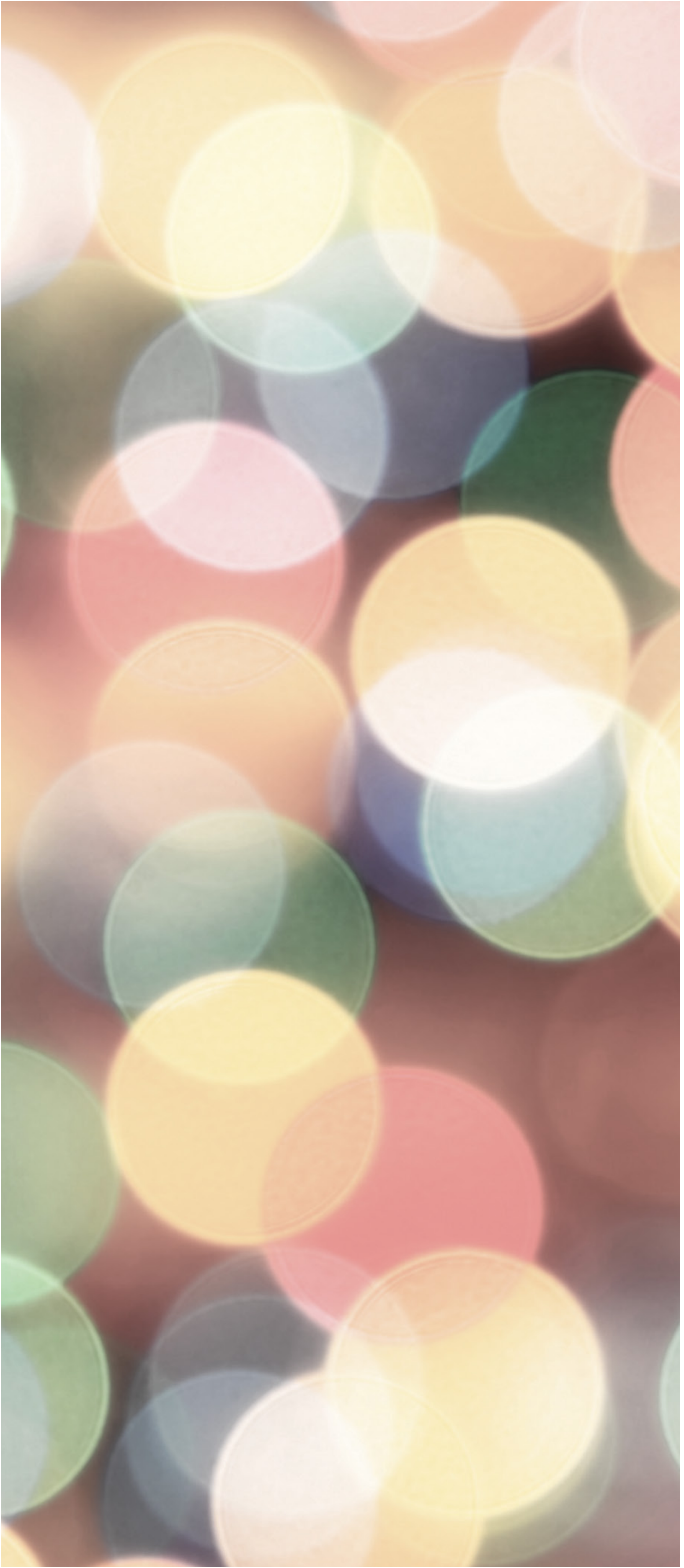
It would be highly inconsistent and contradictory to propose in 500 pages a thesis on the ways in which ubiquitous hypermedia has transformed knowledge. At the same time, because the 37 ideas are independent and make sense both as a cohesive body, but also as a fragmented one -isolated from each other-, it would be just as contradictory to subjugate it to the linearity from which it has distanced itself. The linearity of printed text -which would impose a hierarchization, an order and a consumption logic- prevents me from presenting through this medium the central body of this thesis; for this reason, it can only be accessed through the following website: www.operativeknowledge.net, where the 37 ideas live in permanent reordering. Each visitor will face a random order, one of the 13 763 753 091 226 345 046 315 979 581 580 902 400 000 000 (13.7 tredecillions) ways in which it is possible to organize the 37 ideas that compose the central body of this thesis. This work is an open, dynamic and mutating body that only makes sense before readers that appropriate these 37 discontinuities, and interpret them according to their own reading, needs and context.

It is important to note that the information channel -both as a medium and a device- is a fundamental part of the object being built. The 37 ideas are more than the text that describes them or the image that illustrates them; both components work as parallel languages that build and extend the meaning of what is being shown to the reader -who must not only decode text and image, but also the correlations between them. As Pablo Chiuminatto proposes when introducing his analysis of the images that illustrate the work of René Descartes, "if written words signify, so do the images [that accompany them]; especially images used for illustration and the visual diagrams linked to scientific demonstrations and the concepts explained in the text, for the author has given consent to publish them in his books as part of the graphic exercise of demonstration" (2013) . The image+word duo is a central nucleus of information that constitutes each of the 37 ideas, the order -or disorder- in which the reader faces the task of reading is added to it as an additional semantic space. The most probable scenario is that two individuals will never face exactly the same order, and this is a pragmatic exploration of the fact that all bodies of knowledge and all works are an open space that require a receptor that will iterate the authorial cycle as both a reader and a writer at the same time. Every reading -randomized or not- takes the ideas of the original author and instantiates them through a personal interpretation; this thesis explores this reality by mutating before each reader, and by offering a different field of associations and interconnections to each of them.

www.operativeknowledge.net


Bush
Engelbart
Hofstede
Kay
Licklider
Nelson
Turing
Vygostky
Wiener
Association and Paths of Information
Better Information
Collective Problem Resolution
Connectivity and Mediatization
Culture - Collective Programming
Curatorship, Selection and Context
Document and Repository
Ephemeral Orders
Hierarchies and Contexts
Human-Computer Counterpoint
Hyperlinks
Individual and Community
Information and Communication
Information and Entropy
Information and Interconnection
Interaction and Ideas
Internal and External Model
Internal Dialogue and Our Understanding of the World
Language Acquisition and Use
Linearity
Medium & Technology
Operative Knowledge
Organization, Form and Use of Information
Partial Observation
Personal and Collective Intellect
Procognitive Systems
Programmed Ignorance
Read and Write
Real-Time Systems
Retrieve, Use and Generate
Sharing Points of View
Space and Time
Specialist and Generalist
Specialization and Interconnection
Technological Symbiosis
Technology and Communication
Words and Things


“Conclusions”



Afternotes

The 37 ideas that build the central theoretical body of this thesis follow the emergence of operative knowledge –from its cultural and communal contextualization to its pragmatic enabling by technology. A reading of these 37 fragments as a continuum body of knowledge can build the following afternotes:

- Hyperlinked registries and hypermedia systems are the technological episteme that compose the seminal basis for today's information and communications revolution; by transforming the way we relate to media objects, hyperlinking capabilities have changed our cultural scenario.
- Operative knowledge –understood as little fractions of knowledge of quick and superficial access that allow individuals to consume, create and transform ideas- is the consequence of today's hyperlinked information environment; it allows ideas to circulate and be applied to real life scenarios across disciplinary and cultural boundaries –even if those applying them are not experts or if the information lacks depth or completeness.
- By interacting with hypermedia systems, users have left behind the traditional role of passive receptors of content, establishing two-way communication channels; the traditional division between content creation and consumption has blurred, allowing users to not only access the information registry, but also transform it.
- The shift from physical to digital libraries has reconfigured our saving, searching and finding policies and strategies; harnessed by the power of search algorithms and search engines, today's access to online repositories is an ongoing dialogue between multiple users who operate as content read-writers.
- Operative knowledge is enabled by the ubiquitous availability of online hypermedia repositories, which we access through multiple interfaces that are permanently available to us.

Future use

I hope that the work presented in this thesis is seen as a first and open draft that attempts to conceptualize the technological mediation of knowledge. In no case do I intend this to be an exhaustive or definitive approach towards the issue. I hope that by making this work available online, someone might find this in the future and be called to action, and that the 37 ideas that I propose here become a useful tool to analyze, comment and understand the ways in which technology is transforming knowledge all around us.

An open and unanswered question is how our educational systems will react to operative knowledge. It is fundamental that we update our understanding of what learning is, and the purposes it serves. We need to stop thinking of education in terms of specific activities like reading, memorizing, or conducting math operations, and begin to include in our metrics of educational success more outcomes that directly relate to our daily activities, needs, and challenges. Operative knowledge opens a window of opportunity to understand education as a means towards an end that lies beyond our immediate and standardized ways of assessment.

Finally, I must add a word of caution: although the hardware and software required to access virtual spaces exist all around us, and therefore operative knowledge is permanently enabled and accessible, there seem to be settings where the technological mediation of knowledge and culture will be delayed, and find more resistance and barriers of entry (**Paper IV**). This could be purely anecdotal, and technological mediation could reach them in some form sooner or later; but maybe, as technology continues blazing its trail towards permanent and ubiquitous connectivity, we will see the emergence of a counter phenomenon, spaces and times where technology is actively rejected. Will this happen? It's definitely too soon to know.

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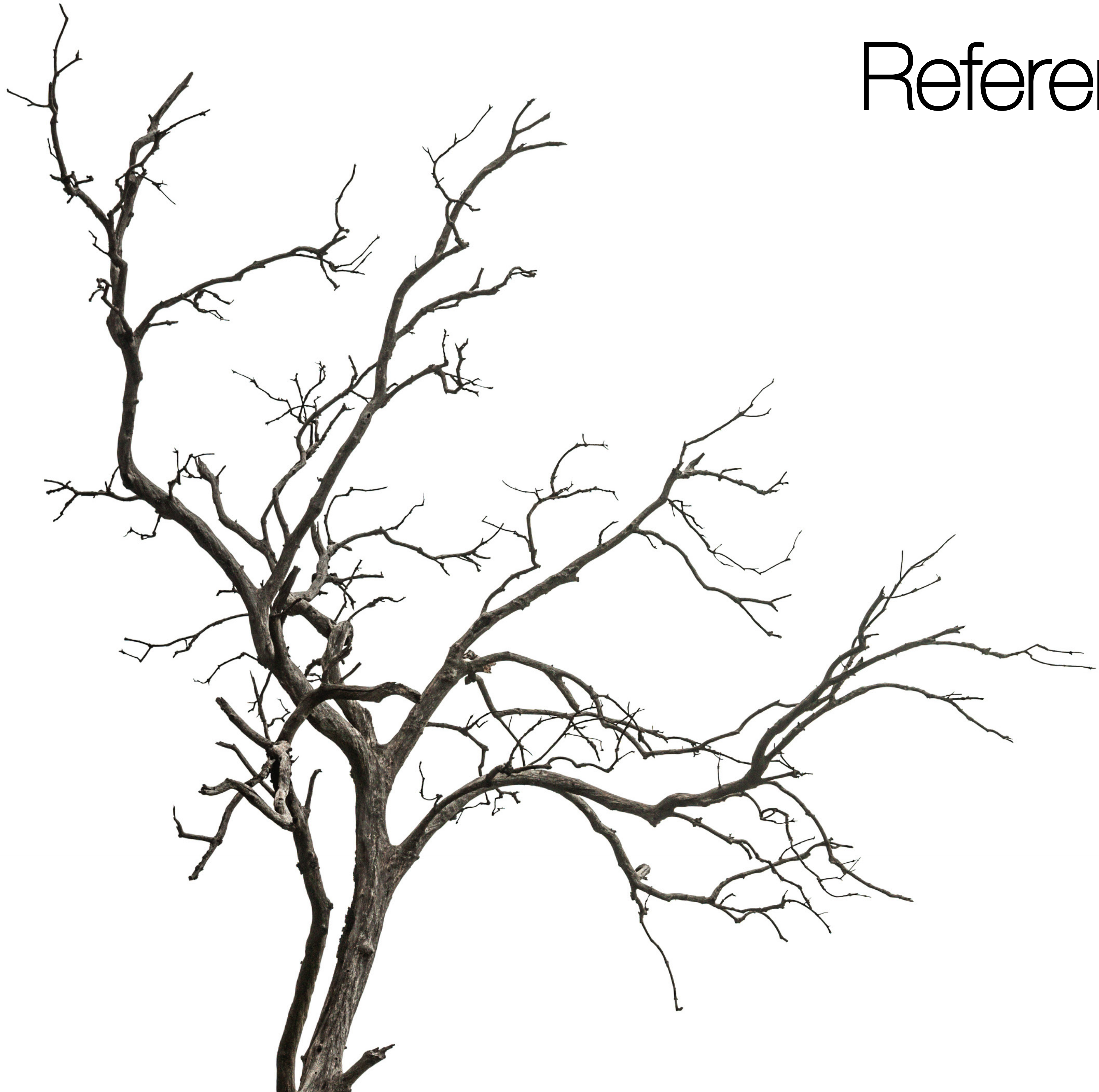

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APPENDIX A

PAPER I

Preparing Undergraduate Computer Science Students to Face Intercultural and Multidisciplinary Scenarios

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Teaching Case

Preparing Undergraduate Computer Science Students to Face Intercultural and Multidisciplinary Scenarios

—RENATO VERDUGO, MIGUEL NUSSBAUM, MAGDALENA CLARO, MARCOS SEPÚLVEDA, BORIS ESCOBAR, RICARDO RENDICH, AND FERNANDO RIVEROS

***Abstract*—Problem:** *This teaching case presents the authors' experience planning, teaching, and evaluating a semester-long course within a computer science undergraduate program; the aim of this course was to develop soft skills that enable students to actively contribute within multicultural and transdisciplinary teams.* **Research question:** *How can an undergraduate-level course help computer science students better understand the multicultural and interdisciplinary scenarios that compose today's working environment?* **Situating the case:** *The literature review contextualizes the case as part of a broader group of literature concerned with curricular reforms that replace the traditional emphasis on memorization of fixed disciplinary knowledge with what have been called "21st Century Skills." In addition, it builds a theoretical framework followed by the course that brings together Hofstede's Cultural Theory and Vygotsky's ideas regarding the social formation of the mind.* **Methodology:** *The researchers conducted two studies with a group of 62 students who participated in the course. The first one measured how students appropriated the concepts presented in the course and learning outcomes. The second one evaluated the students' perception of the course a year after they had enrolled in it. About the* **teaching case:** *Results show that the vast majority of students appropriate the concepts of the theoretical framework used throughout the course. In addition, most students perceive the courses' contribution to their professional lives positively—particularly regarding understanding cultural and transdisciplinary issues. A small group does not consider a course like the one proposed to be useful.* **Conclusions:** *The implication of this teaching case is that the ability to communicate effectively with a range of audiences is something that can be addressed directly by a specifically designed course within a computer science curriculum (rather than exclusively being a secondary outcome of other courses). The limitations of the study are that it presents the authors' own teaching experience (therefore, it is not a third-party report) and that it uses pretesting and posttesting as an asessment tool for multicultural and transdisciplinary abilities. Future work would show how similar experiences could be conducted across other cultural scenarios and possible ways in which to engage the small group of students who do not consider the course useful.*

Index Terms*—Communication, culture, Hofstede, information technology (IT), intercultural communication, interdiscipline, Vygotsky.*

This teaching case presents our experience planning, teaching, and evaluating a semester-long course within a computer science undergraduate program; the aim of this course was to address the fact that today's engineering education must not only provide technical training, but also soft skills that enable students to actively contribute within multicultural and transdisciplinary teams. As noted by the ACM/IEEE Computer Society Curriculum Guidelines for Undergraduate Programs in Information Technology, and the ABET Criteria For Accrediting Computing Programs, a required program outcome—that is to say, a skill that the program enables students to achieve by the time of graduation—is the "ability to communicate effectively with a range of audiences" [1, p. 18], [2, p. 3]. Finding and exploring different approaches to this requirement is relevant to engineering and computer science schools undergoing curricular planning processes. This teaching case is guided by the following research question: How can an undergraduate-level course help computer science students better understand the multicultural and interdisciplinary scenarios that compose today's working environment?

This paper begins by situating the case within the literature and then presents the methodology followed while documenting it. Detailed descriptions of the undergraduate course developed are provided, along with empirical data that evaluates student outcomes and reception of the course. The final section of this paper presents conclusions that discuss the implications the teaching case has

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on computer science education and professional practice, along with the case's limitations and suggestions for future work.

SITUATING THE CASE

This section contextualizes the teaching case by explaining how it responds to the need to prepare students to face multicultural and interdisciplinary working environments, along with the literature from which it draws its main concepts. It first describes how the literature was selected from which to situate this case. Next, it explains two key concepts underlying the case: interdisciplinary and multicultural environments that today's students face, and the Vygotskyian framework that scaffolds the course being presented.

How Literature was Selected The course's literature was selected based on our previous work and experience in education; the courses we have taught in the past have served, throughout the years, as pilots of the evaluation methods and the bibliographic framework that build this course's theoretical and practical underpinnings. Vygotsky's conceptualization of cultural mediation and interpersonal communication allowed us to establish a solid theoretical foundation from which to initiate a rich dialogue with our students about interdisciplinary and multicultural environments.

Interdisciplinary and Multicultural Environments Information and communications technologies (ICT), globalization, and knowledge-centric societies, have produced radical changes regarding the abilities and skills required to actively contribute and collaborate within culturally diverse and interdisciplinary working environments. These changes have emphasized the need to transform educational practices in order to train new generations to be aware of the communicational difficulties these new scenarios present. In fact, several initiatives are pushing for curricular reforms—at all levels of the educational system—that replace the traditional emphasis on memorization of fixed disciplinary knowledge with what have been called "21st century skills." These transdisciplinary skills are related to higher order thinking processes and interpersonal capabilities. Common examples of these skills are communication, creativity, collaboration, critical thinking, and ICT use.

Among the most important international initiatives promoting changes regarding the way we prepare future generations for the challenges ahead are: The Partnership for 21st Century Skills [3], the ATC21S Project [4], the OECD DeSeCo [5], the OECD PISA [6], and the Lisbon Council of the European Union [7]. These initiatives stress the importance of teaching students to communicate effectively with others in increasingly diverse social and cultural contexts. For example, the OECD Key Competencies Framework argues that "as societies become in some ways more fragmented and also more diverse, it becomes important to manage interpersonal relationships well both for the benefit of individuals and to build new forms of cooperation" [8]. These competencies are considered crucial for individuals to learn, live and work with others, and are addressed with terms such as "social competencies", "social skills," "intercultural competencies," or "soft skills."

In addition, the Framework for 21st Century Learning [9] describes basic abilities that students must have in order to succeed in work and life, when facing today's world. It broadens the way we understand communication by proposing skills related not only to the effective exchange of ideas, but also the understanding of social, cultural, and diversity issues involved when interacting with others. Facing today's multicultural environment and being able to communicate effectively with a range of audiences goes beyond the way we express ideas and requires us to know how to "respect cultural differences and work effectively with people from a range of social and cultural backgrounds" [9, p. 7].

Vygotskyian Framework Scaffolding Our Course Twenty-first century skills require that undergraduate programs prepare students to excel not only in the technical aspects of their disciplines, but also to understand how we differ from others and how to embrace these differences in order to collaborate effectively, enrich and complement our ideas, and interact respectfully with people from diverse backgrounds and different points of view. Intercultural and transdisciplinary abilities require students to be fully aware of the communicational dimensions involved when individuals of diverse cultural and disciplinary backgrounds interact. To help students achieve this awareness, the course's focus was placed on how culture and knowledge are social constructions; on how individuals configure their existence through human collectives and by interacting among each other. The theoretical framework was based on two seminal authors whose ideas revolve around social interaction as a driving force of human experience: Vygotsky and Hofstede. Vygosky's ideas regarding the social formation of the mind [10] and Hofstede's conception of culture as a "collective programming of the human mind" [11, p. 24] offer a broadened understanding of communication as a socially and culturally situated process.

Vygotsky's proposal that it is through interaction with others that we become ourselves [10] is central to understanding cultural and disciplinary differences. He proposes that mental processes and human actions, like communication and concept creation, be socially mediated. The idea is that all psychological functions are culturally, historically, and institutionally situated and context specific [12]. Vygotsky enunciates that:

> traits of human personality, which are latent in every human being due to the organic makeup of heredity, exist in the environment, but the only way they can be found in each individual human being is on the strength of his being a member of a certain social group, and that he represents a certain historical unit living at a certain historical period and in certain historical circumstances. [13, p. 352]

Because of this, communication is a process that transcends the realm of idea exchange and is deeply related with an individual's culture and identity.

A Vygotskian reading of Hofstede's ideas has been proposed by other authors, noting that "'collective programming' is not to be understood as an external imposition but an active social composition in which the particular individual plays the protagonist" [14, p. 262]. Based on these propositions, a conceptual framework is presented and explained in Table I. Culture is the pivotal concept of the framework, providing the general context and backdrop for a process that begins through social interaction and communication, and leads to the construction of an individual's inner speech—his/her own representation and modeling of the surrounding environment—and how this configures a (partial) observation of the world around him/her. The framework enables the understanding of social context and cultural background as relevant components of the process of communication; it also suggests the double nature of the link between them, because cultural and social environment influences communication while, at the same time, communication is a shaping element of said environment. What all of this configures is a broader understanding of communication and social interaction, where message construction and exchange are the cornerstone for cultural diversity and individual identity.

We opted to limit the bibliography to exclusively Hofstede and Vygotsky; although their ideas can be tracked back and forth through a network of social science references, we considered that extending the bibliographical scope of the course might shift its focus; an extensive literature review would have distracted our students from our goal—to get them to gain real-life experience handling interdisciplinary and multicultural scenarios.

METHODOLOGY

This teaching case is guided by the research question: How can an undergraduate-level semester-long course help computer science students better understand the multicultural and interdisciplinary scenarios that compose today's working environment? It is an experience report, based on our own teaching experience which includes planning, teaching, and evaluating a course to be included as part of the minimal curricula of an undergraduate computer science program.

The sources of data for the study are two separate activities that were incorporated into the course's planning. The first source is a pretest and posttest based on open-ended questions that were designed and validated by a group of professors, teaching assistants, and recent graduates from the program. Pretesting was done as soon as students enrolled in the course, before classes began, and, therefore, students knew nothing about the contents of the course; the posttest was applied at the end of the semester once all evaluations had ended. For pretesting and posttesting comparison, independent expert evaluators tabulated the students' answers into predetermined quantitatively analyzable categories. The second source of data is a voluntary survey that students were asked to answer a year after they had enrolled in the course, which was composed of two open-ended questions.

For both sources of information, all answers were anonymous and evaluators could not trace answers back to their authors. Students were informed that the study was being conducted throughout the semester and because of the fact that the sources of data were not part of the compulsory activities of the course, they had the option to opt out of the study.

TABLE I
THEORETICAL FRAMEWORK

Culture		
As noted by Hofstede, culture corresponds to "the collective programming of the human mind that distinguishes the members of one human group from those of another" [11, p. 24]. Individuals therefore live their lives not as isolated beings, but as members of specific collective communities determined by their context and social interactions.		
Communication	**Representation and Modeling**	**Partial Observation**
Culturally situated individuals face the need to interact with their social environment using and acquiring language and speech as a means of communication with others [15]. Said language depends on the particular context of the individual; as noted by Vygotsky, people do not invent their own language but "find the words in a ready-made state, fixed to ready-made things" [13]. Assimilating language and the links between objects and words enables an external speech dependent on social interactions. Therefore, language is initially a tool taken from the environment that configures naming and referencing abilities, enabling two-way communication between context and individual.	According to Vygotsky, because of the external speech enabled by communication, we gradually learn how to use language for our own inner thinking process–inner speech [13]. The connection between speech and thought takes language beyond the realm of external interaction with the environment and becomes a key structural component of an individual's thought process, logical reasoning, and the formation of concepts. Transcending the link between words and context, the use of language evolves into a much richer process of representation and modeling, understood as the process where individuals make sense of the world around them.	Because of the different understandings of the world we live in, which originate from the individual's representation and modeling process, life is seen through multiple points of view. Therefore, each individual has a partial observation of the richness of human experience and any given understanding of reality is only one within multiple others. Through this differentiation process, human beings configure complex and intricate webs of multiple individuals with different knowledge, emotions, paradigms, and values. A person's partial observation of the world may be understood as his/her mental model, the prism through which external and internal events are understood and analyzed.

ABOUT THE TEACHING CASE

This section presents a detailed description of the planning, teaching, and evaluation of the course we created to address the need to incorporate "soft skills" into the computer science program at our university. We first describe the problem that motivated its creation and then provide a brief description, a brief walkthrough, and facts about the course; finally, we close this section by documenting the process for developing and piloting the course.

Problem During a major curricular planning revision of the computer science program at our university, the committee faced the need to incorporate "soft skills" into the core compulsory courses. Previous curricula was highly technical and 21st century skills were only addressed as secondary byproducts of other courses; there was increasing awareness among some faculty members and alumni, with some years of professional experience, that graduates from the program lacked some of the necessary skills that enabled them to work effectively with people from disciplinary backgrounds other than computer science.

Course This section describes the course. To provide a context for later discussion, this section starts by explaining the purpose of the course, then briefly walks through the course and explains the process for developing and teaching the course, and closes by describing the results of the course.

Purpose of the Course: The purpose of the course was to give students the ability to understand and critically analyze the communicational competencies involved in interdisciplinary and multicultural interactions. By understanding the ways in which our day-to-day lives are built, modeled, and influenced by cultural contexts and social contact, students would be able to see the broader picture involved in human interactions and understand communication not only as the punctual exchange of information between people but also as the fruitful encounter of different cultural backgrounds and life experiences. Embracing this phenomenon would better prepare students to develop and understand the key communicational competencies that effective interdisciplinary and transcultural communication requires.

This program was designed for an audience of third-year undergraduate students from a computer science program. Because of the student's disciplinary background, the main focus was on interdisciplinary and multicultural scenarios where technological mediation or integration was somehow involved in each situation.

Brief Walkthrough of the Course: During 16 weeks, a group of 70 students had one, 3-h lecture session per week where each of the three conceptual areas of the theoretical framework was presented through key concepts and their definitions (Table II). The main activity that composed each lecture session was to conduct in-class discussions, specified in Table II, based on multiple examples from various sources (books, magazines, newspapers, movies, blogs, podcasts, videos, etc.). As time goes by and the course is taught multiple times, the examples used to fuel the discussion are meant to be constantly updated with new material that students recognize as current and familiar; this way, students can relate to the examples, more actively contribute to in-class discussions, and better appropriate the concepts being presented. An atmosphere of constant interaction and participation was nurtured by allowing students to freely comment on the examples seen in class and by encouraging students to present their own examples and testimonies. The constant mediation of the course's professor was meant to guide the discussion and reinforce the concepts being presented.

Along with the weekly lectures, students had to work in groups throughout the semester, analyzing a "human organization" of their choice that was going through an information-technology adoption process. To provide students with further freedom, "human organization" was broadly defined as any scenario where two or more people meet periodically to work together. Groups had to analyze the organization they were working with according to the concepts seen in class, document their understanding of the technology adoption process they were facing, and propose intervention opportunities that could help the organization achieve their proposed goals. A total of seven deliverables were established; each one had particular objectives relative to the development of the project and required students to hand in their work using particular media languages (Table III). The group project served a double purpose; it allowed students to transfer the contents of the course into a real-life scenario and because of the medial languages used, it enabled students to further understand how message construction works and gave them concrete tools to communicate effectively with others. The Appendix, which is available online as downloadable supplementary material at http://ieeexplore.ieee.org, shows examples of work conducted by students during the course.

Process for Developing and Piloting the Course: The process for creating, planning, and teaching this course had six key milestones that are sequentially presented in Fig. 1.

The first milestone consisted of a broad revision of literature regarding 21st century skills in order to determine the subset of areas the course would address. The deliverable produced during this phase consisted of the three main areas the course would focus on (Culture, Knowledge, and Social Interaction). The areas selected were those that better addressed the objective of the project: to approach interdisciplinary and multicultural issues through an undergraduate course within a computer science program.

The deliverable of the first milestone served as the input for the second deliverable. The search for the basic bibliography was conducted by narrowing the focus to three relevant areas. The seminal authors that were selected—Hofstede and Vygotsky—have been thoroughly studied and applied to diverse educational scenarios. The deliverable for this phase was the articulation of the theoretical framework presented in Table I.

Having determined the areas the course would address, as well as the main bibliographical references and the overall theoretical framework, we established the expected outcomes of the course; the idea was to lead students toward an appropriation of the concepts from the theoretical framework in order to apply them to multiple real-life scenarios. To achieve this, we decided to use Bloom's Revised Taxonomy [16], which defines six consecutive cognitive processes of increasing complexity: Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. The first three relate to lower cognitive processes and the last three relate to higher order thinking. Table V shows the expected outcomes for each stage, regarding the concepts from the theoretical framework.

In order to achieve the expected outcomes determined according to Bloom's Revised Taxonomy, it was established that the course's methodology would have two main components:

TABLE II
STRUCTURE OF THE COURSE: CONCEPTUAL AREAS, KEY CONCEPTS AND TOPICS OF DISCUSSION

Conceptual Area	Key Concepts	Week	Topics of Discussion
Culture	Culture; community	1	Where can you identify traces of a "collective programming of the human mind"?
		2	Analyze a broad set of variables that are culturally determined; which are explicit (like language) and which are implicit (like the relation to death)?
		3	How does culture determine our sense of community? How does our culture distinguish us from those who belong to other cultures?
Communication	Message construction; signs and language; effective communication	4	How are messages built and how do they work? Consider semiotic approaches.
		5	How do medial languages influence the structure and effectiveness of messages? How do meaning and message change when translating between different codes and languages?
		6	What is the process of communication? What happens when a sender and a receiver interact?
		7	In what ways does language, both verbal and non-verbal, expand and limit our communication abilities? How do objects, the relations established between them, and the context in which this is done mediate our communication ability?
Representation and modeling	Modeling; data, information & knowledge; mental models; paradigms; heuristics	8	How are representations a way to synthesize reality? Is it true that they are always based on someone's perception of reality?
		9	How do cultural and social contexts bias perception?
		10	How do we build our mental model? Consider how facts, rules, and paradigms configure our identity.
		11	How do heuristics facilitate the modeling process? How do models and representations affect the world around us in real-life scenarios?
Partial observation	Diversity; completeness and consistency	12	Is diversity a basic component of the world we live in? Critically analyze the ways in which gender, age, nationality, culture, and other variables configure multiple points of view.
		13	How do completeness and consistency influence the way we understand the world around us?
		14	Is decision-making affected by our points of view and perspectives? Analyze the way others understand the world around them and empathize with their reasoning and partial observation of the world.
		15	How do our limited rationality and the information we have access to fix our understanding of the world we live in?
		16	How does working with experts and transdisciplinary teams enrich our own perspectives and points of view?

one process fully guided by the professor and the teaching assistants of the course, and another where students would freely determine the work they would develop. Through the weekly lecture sessions, where key concepts would be presented and discussions held, the first three cognitive processes would be addressed; students would be presented with different scenarios and oriented regarding the applicability and use of the conceptual framework. Through a group project, students would have to apply higher order thinking by facing unfamiliar situations. No longer sheltered by the guided process followed in class, they would have to transfer the concepts from each conceptual area into real-life situations that were not specially designed as instructional scenarios. By having these two separate components, the course would enable students to go through all six cognitive processes defined by Bloom, taking the conceptual framework beyond the theoretical understanding of the concepts and appropriating them so as to be able to use them in unfamiliar real-life situations.

TABLE III
GROUP PROJECT SPECIFICATIONS

Milestone	Media Language	Objectives and Description
Presenting the context: project proposal	Written report	Groups had to present an overall view of the human organization they wanted to work with and the information technology process it was facing, through a professional written report. This allowed them to concisely explain to the teaching assistants what their proposal was.
Understanding the human organization: culture and community	Online wiki	Groups had to build a knowledge base using an online wiki system where they would explicitly document their understanding of the human organization's specific culture and sense of community. Encyclopedic writing pushed students to unambiguously explain subjective perceptions that would otherwise go unnoticed or undocumented.
Explaining to others: effective communication	Podcast (audio)	Groups had to explain to their fellow classmates and a general audience what their project consisted of and the information they had gathered so far. Through their work, students developed expert knowledge about their project; addressing an audience that had no previous information about the project required students to find ways to communicate to others that which to them seemed familiar yet was hard to explain. Audio adds complexity to this issue by removing all visual aids, and forcing the use of verbal communication.
Finding a problem: mediation and intervention	Online video	Groups were asked to find problems the human organization was facing regarding the technology adoption process. Additionally, they had to find mediation and intervention opportunities where, by applying concepts seen throughout the course, they could help the human organization to overcome its problems. Video allowed students to creatively mash-up audio, text, images and moving images, by doing this, they could choose from a broad range of resources that enabled them to communicate their message.
Showing what we've learned so far: mental model	Mind map	Groups had to graphically present all the information they had gathered through a representation of the mental model they had formed throughout the project. Mind-mapping provided a natural and intuitive environment to achieve this purpose.
Hearing others' opinions: completeness and consistency	Facebook discussion group	An important objective of the project–and the course-was for students to become aware that when facing a problem and choosing a solution, any alternative taken will be one among many others. This milestone required groups to ask relevant actors–either people from the human organization or other target audiences they determined- to review their work and provide feedback. To do this, they had to create a Facebook group where discussion forums were available and users were actively encouraged to participate and provide feedback.
How we saw it: partial observation	Online magazine	As a way of consolidating the whole process undergone throughout the project, groups created an online magazine. By using a written document that integrates images, video, audio and any other resources they needed, students were able to provide a complete deliverable that was also easy to read and understand, which documented their semester-long work.

TABLE IV
FACTS ABOUT THE COURSE

Item	Description
Budget	No special funds were allocated for the development and testing of this course. Design and development were part of the regular responsibilities of the faculty member and teaching assistants in charge of the implementation.
Allocated time	One senior faculty member was assigned 10 hours a week to work on the project during 10 months. Two teaching assistants were assigned 5 hours a week to work on the project during 10 months.
Length of project	The course required a full academic year from beginning to end (5 months of planning and 5 months of teaching and evaluating). The follow-up survey conducted a year after students had enrolled in the course required an additional month of work by the team a year later.
Software required	All in-class discussions required MS PowerPoint presentations to show examples and media content. Media editing and production software was used to create materials for the class (Adobe Photoshop and Adobe Illustrator for illustrations and images, Adobe Premiere for video editing, and Audacity for audio editing). Additionally, despite the fact that students were free to choose the software used for each of the project's milestones, the following software and online tools/services were suggested: MS Word, Wikispaces.com, Audacity, YouTube, Windows Movie Maker, iMovie, Facebook, Blogger, and Wordpress.com

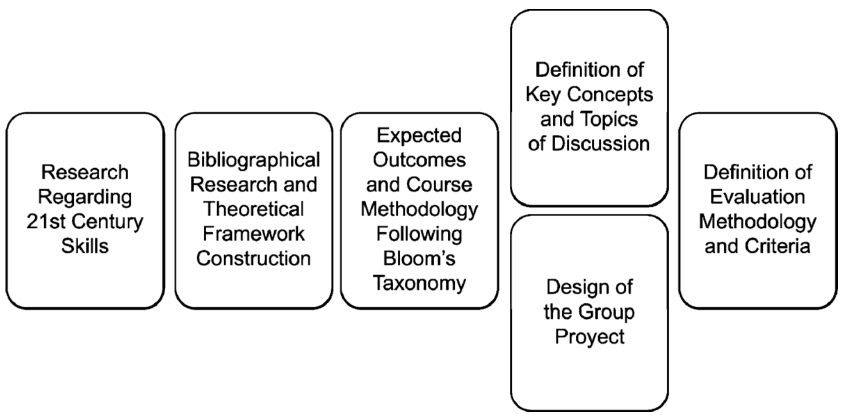

Fig. 1. Key milestones of the process for developing and piloting the course.

Having established the expected outcomes following Bloom's Revised Taxonomy, two parallel tasks were developed: selecting key concepts and discussion topics, and the design of the group project for the course. For each conceptual area of the theoretical framework, a series of key concepts and discussion topics were determined (as seen in Table II). Although multiple additional or alternative topics could have been selected, the criteria used considered the time constraints the weekly sessions imposed and how relevant they were to the particular context under which the course was being designed. If the course was replicated under different scenarios, the topics of discussion would have to be adapted to new contexts and time constraints.

As an alternative to the in-class discussions methodology, the team considered two other options: expositive lectures where students would participate through weekly written essays, or focalized study groups where the class would be split into smaller groups. The first option provided the benefit of ensuring the participation of all students by forcing them to hand in weekly essays; unfortunately, this methodology would have meant that students worked alone throughout the semester and would have not discussed the course topics with their classmates, thus losing the enrichment that idea exchange provided to the course. The second methodology would have required additional professors or teaching assistants to mediate the discussion within smaller groups, and those resources were unattainable at the time the course was being planned.

Regarding the group project, the deliverables this milestone built were the specifications for the semester-long project that students would develop. The main decision made was the degree of freedom students were given. One alternative was for the professor and teaching assistants to determine a set of projects that would later be assigned to each group. This idea was discarded because it

TABLE V
EXPECTED OUTCOMES FOLLOWING BLOOM'S REVISED TAXONOMY

Cognitive process	Expected outcome regarding the use of concepts from the theoretical framework, when facing interdisciplinary and multicultural scenarios.	Achieved mainly through
Remembering	To be able to recall concepts from each conceptual area.	Lecture sessions
Understanding	To be able to explain concepts from each conceptual area.	
Applying	To be able to use concepts from each conceptual area in familiar situations.	
Analyzing	To be able to break information into parts, exploring the relationship between the current situation and past experience. To understand the applicability of the concepts from each conceptual area under unfamiliar situations.	Group project
Evaluating	To be able to diagnose the cause of difficulties faced under the current unfamiliar situation, and explain them based on particular concepts from each conceptual area.	
Creating	To be able to propose intervention opportunities to overcome the difficulties faced under the current unfamiliar situation, and justify them based on particular concepts from each conceptual area.	

would have replicated the sheltered environment that in-class discussions created. Alternatively, the purpose and objectives of the project were first explained to the students, who were then given a week to find a “human organization” of their choice that was undergoing a technology adoption process, with which they would work throughout the semester. To ensure that all groups chose projects with similar scopes and difficulty levels, each group had to develop a project proposal. If the teaching assistants considered the proposal to be either too broad or too narrow, they gave students an additional week to either rewrite their project or propose a new one. An additional decision point was whether to incorporate a technological adoption process as a compulsory requirement for each project. Both strategies would have resulted in successful projects, but because of the fact that all participants of the course were computer science undergraduate students, this additional requirement better fulfilled the idea of preparing students to face their future work environments.

Finally, once the course was completely designed and ready to be taught, the team focused on how to empirically assess to what extent students had appropriated the concepts of the theoretical framework and their overall perception of the course. The deliverable for this milestone was the data-collection instruments and methodologies that would be used to conduct an empirical evaluation of the teaching case. As explained in the methodology section, two sources of information were selected: a pretest and posttest evaluation and an open-ended question survey conducted a year after students enrolled in the class.

When choosing pretesting and posttesting as an instrument to measure intercultural and multidisciplinary competencies, it was necessary to consider the fact that these competencies depend on a combination of acquired attitudes, skills, and knowledge [17]–[20]. These skills and attitudes require time and exposure to intercultural experiences in order to be developed; therefore, assessing competencies, in general, and intercultural competencies, in particular, is a complex process. It would be challenging—if not impossible—for one tool to measure an individual's intercultural competence on its own [18], [21]. As Deardorff [18] proposes, for short-term programs, expected outcomes must realistically match the length and learning interventions of the program and, therefore, in the context of a one-semester course we decided to measure competence at a cognitive and reflexive level, accepting the tradeoff of not considering the full process that competence acquisition carried along.

Assessment can be obtained through direct or indirect evidence; one source of direct evidence is critical reflection, which is an essential procedure in order for learners to develop intercultural competencies [17]. To measure critical reflection, students were presented with three online videos and asked open-ended questions (Table VI). The videos described general situations that were polysemic and could be understood differently, according to the student's particular interests and

TABLE VI
PRETEST AND POSTTEST USED TO ASSESS THE IMPACT OF THE COURSE

Video	Main conceptual area involved	Questions
Orchestra interpreting 4'33" by John Cage [22].	Communication	Does the musical piece have any value? What transcendence does it have? Is the composer of the piece an artist? Is there a message in the piece? Do we understand it? Why does the audience applaud at the end?
A scientist is denied access to a nuclear lab to prevent an accident, because he does not have his ID with him [23].	Representation and modeling	What problems can you identify in the video? Why do these problems happen? What solution do you propose?
Public service announcement from Japan [24].	Partial observation	What is the ad's message? Who is it addressed to? If you had to transmit this message to someone, how would you do it?

disciplinary background. The questions, which had no correct or incorrect answers, asked students to describe general aspects of the situations presented to them, and did not focus particularly on any of the course's concepts. Questions were meant to guide students toward a deep analysis of the situations being presented but without forcing the use of any of the course's concepts.

The idea was to empirically measure the use of the concepts presented throughout the course, and how they changed students' capacity to observe, diagnose, and intervene in situations involving multiple cultures and disciplines. Evaluating how concepts naturally appeared in the students' answers reflected how they had become structural components of the students' inner speech, aiding in the understanding of the world around them.

Expert evaluators, using the key concepts and discussion topics from Table II as the observation form, read each of the students' answers and determined the presence and use of the concepts. For each of the four conceptual areas presented in Table II, answers were classified into one of the following categories:

- "Concepts from the conceptual area are explicitly present and central to the ideas presented in the student's answer." (3 points)
- "Concepts from the conceptual area are explicitly present but peripheral to the ideas presented in the student's answer." (2 points)
- "Concepts from the conceptual area are insinuated within the student's answer." (1 point)
- "Concepts from the conceptual area are absent." (0 points)

To further assess the impact of the course, a year later students were contacted and asked to answer the following open-ended questions:

(1) Do you think the course helped you better understand the difficulties you face when communicating with people from backgrounds different from yours?
(2) If you had to add a tagline to this course, what would it be?

Asking students to create a tagline for the course forced them to condense what they thought was its main idea into a single phrase and this made it possible to evaluate how students perceived the course and its contribution to their professional and personal lives. Expert evaluators familiar with the contents of the course were used to categorize students' answers to both questions into one of the following categories:

- Positive: The answer presents only positive aspects.
- Positive and negative: The answer presents positive and negative aspects.
- Negative: The answer presents only negative aspects.

Results: Pretests and posttests were conducted with 62 participants and show statistically significant differences between pre and posttests for all of the conceptual areas defined in Table II. The numerical values assigned to each category

TABLE VII
GROWTH FACTOR OF CONCEPT USE AND PRESENCE BETWEEN PRETEST AND POSTTEST. (SAMPLE SIZE: 62 STUDENTS)

	Growth Factor	*p*
Culture	1.591	0.00116
Communication	2.566	1.95E-15
Representation and modeling	3.301	6.25E-14
Partial observation	3.178	1.43E-08

TABLE VIII
EXCERPTS FROM OPINIONS GIVEN BY STUDENTS A YEAR AFTER ENROLLING IN THE COURSE

	Do you think the course helped you better understand the difficulties you face when communicating with people from backgrounds different from yours?
Positive	"...It showed me that unexpected behaviors and reactions by people are not random but actually have logical explanations..."
	"...It gave me a model to understand things that one intuitively knows, but does not know how to express..."
	"...It shows students that ideas that we think are unique and unbeatable may not be so..."
	"Yes. Throughout college we have been taught an "algorithm" that slowly defines the way in which we solve problems, face different situations and interact with people. This course shows students that, despite the fact that said "algorithm" is good, there are many other ways of facing diverse situations and relating with other people... And in many cases, they are better than ours!"
	"It was useful not only within computer science but on a broader level. The course gives tools to understand and appropriate the way we communicate and learn."
	"As engineers, we tend to over credit ourselves and think we are always right, underestimating other opinions. This course teaches you a fundamental value: a global understanding of the fact that the world has as many points of view as people observing, and that they are all valid. (...) This course opens a window towards bridging the gap between us as individuals, and the rest of the world."
	"Although one can communicate effectively with people without going through this course, it is very useful to have a formal education and a model to understand how it actually works."
	"...It helped me understand I can never say I am 100% right, because many people may see things differently than I do."
	"...It showed me that computer science goes way beyond technical knowledge (i.e. Programming skills)."
	"Yes. It made me realize the biases under which I live my day to day life."
Negative	"I cannot see how this course is useful; despite being very interesting, it does not go beyond being a compendium of knowledge about the human being."
	"No. I believe that the things taught in this course cannot be taught in a course."

allow an analysis of the variation between pretests and posttests. Table VII shows the growth factor, between pre and posttests, of the use and presence of concepts from each conceptual area.

Results show that students were able to appropriate the concepts presented to them and transfer what they learned to the scenarios presented by the videos shown during the tests; this is true for each of the concepts present in the theoretical framework. Pretests and posttests show significant growth in the students' ability to identify cultural differences and interdisciplinary difficulties based on the theoretical framework used in the course. Culture shows a smaller growth between pre and posttests, in proportion to the other variables; this can be explained because, when first enrolled in the course, students know more about culture than they do about the other variables, suggesting the other variables are more novel to them and, therefore, they show a greater increase between pretest and posttest evaluations.

Evaluators commented on the fact that most of the pretest answers were very restrictive and judgmental (for example, in pretests, most students considered that $4'33''$ by John Cage was not a work of art and was not interesting) while posttest answers were more flexible and many students warned the reader that their answers reflected their own opinion and were not absolute truths. This suggests that throughout the semester, students

TABLE IX
TAGLINES FOR THE COURSE CREATED BY STUDENTS A YEAR AFTER ENROLLING IN IT

	If you had to add a tagline to this course, what would it be?
Positive	The solution is not always visible from where you are standing.
	An odd course, very weird, therefore… useful.
	Abilities and knowledge that everyone should have, and not everyone has.
	You are what you know
	Let's see the world, but let's really see it.
	A course about concepts that will give you tags to add to things you might already know but will now be able to categorize and organize.
	The only truth is that there is no absolute truth.
	We don't see the world how it is, but rather how we are.
	A different way to see things.
	We are the product of our history.
Negative	A total waste of time.

developed a greater openness to accept the fact that their opinion was partial and others might think differently.

Regarding the survey conducted one year after students enrolled in the course, in question 1, when asked about how the course helped students better understand the difficulties faced when communicating with people from backgrounds different from theirs, 78.7% of the 47 students that participated in the survey answered positively, enunciating ways in which the course had helped them understand interdisciplinary and multicultural issues; 12.76% gave arguments both for and against; and 8.51% considered the course had not helped them achieve the stated objective. Answers show that a year later, the vast majority of students positively value the course's contribution. (Table VIII shows direct quotations from the students' answers.)

When asked to add a tagline to the course, most answers showcase its positive aspects, yet as with the first question, results show a minority of students who consider the course to be useless (Table IX).

CONCLUSIONS, LIMITATIONS, AND SUGGESTIONS FOR FUTURE RESEARCH

This section presents conclusions based on the empirical data presented in this paper and explains its implications within computer science curricular planning and the potential transformation of the workplace where graduates will conduct their professional practice.

Conclusions The experience of creating and teaching the course presented in this paper shows that an undergraduate course can help computer science students better understand the multicultural and interdisciplinary scenarios that compose today's working environment by providing a dedicated space from which to analyze these issues theoretically and practically. By building the course around a core theoretical framework, it is possible to give students a basic bibliographical backbone upon which to discuss and analyze interdisciplinary and multicultural scenarios. Executing real-life projects in parallel to theoretical classes allows students to move from theory to practice. Working beyond sheltered classroom activities helps students better appropriate the concepts and ideas from the theoretical framework while preparing them to face the uncertainties of real-life work.

As required by the ACM/IEEE Computer Society Curriculum Guidelines for Undergraduate Programs in Information Technology and the ABET Criteria For Accrediting Computing Programs, empowering students with the ability to "communicate effectively with a range of audiences" is something that can be addressed directly by a specifically designed course (rather than exclusively being a secondary outcome of other courses). Although it is true that the stated ability must be present throughout the course of any program, the advantages of having a dedicated class are to show students a broader picture regarding the way we communicate and interact with others, therefore, empowering students with additional understanding of the difficulties they will face under today's working scenarios.

Professionals that broadly develop the ability to communicate effectively with a range of audiences and understand how cultural biases and diversity are involved in the process are essential assets for any company or project facing the challenges imposed by today's transculturalized world. 21st Century Skills relate to the ways in which people live and work together, requiring us to embrace our differences and fully understand the world we live in. This will not happen unless we dedicate time and effort to doing so; therefore, curricular planning and design must address this issue in novel ways and challenge students to see the world . . . but really see it.

Limitations The case study presented in this paper faces the following limitations:

- It presents an experience report based on our own teaching experience and is not a third-party report on the teaching case.
- In order to ensure anonymous participation of students in both of the empirical studies conducted, it was not possible to group answers that belonged to the same student in order to compare pre and posttest results with the student's perception of the course a year later.
- To protect student privacy and their right to opt out of this study, none of the graded evaluations that were conducted throughout the course could be used as data sources for this study.
- Measuring intercultural capabilities is a challenging task and the use of pre and posttests offers advantages but also disadvantages. In general, pre and posttests help answer the question: "What changed from the beginning of the program to the end?" This type of assessment design is widely used in behavioral research, primarily for the purpose of comparing groups and/or measuring changes resulting from experimental treatments or interventions. In the assessment of this teaching case, we applied a One-Group Pretest-Posttest Design [25], [26]; Mertens proposes that "although the design has many weaknesses (changes due to history, maturation and testing effects), (...) this design is justified under circumstances in which you are attempting to change attitudes, behavior, or knowledge that are unlikely to change without the introduction of an experimental treatment" [26, p. 133].

Suggestions for Future Research The teaching case presented in this paper is specific to the context under which it was created and, therefore, its validity across other contexts configures a possibility for future work. The theoretical framework along with its key concepts can be replicated in different contexts, yet the discussion topics and examples used throughout the course must be customized to the specific teaching scenarios—different locations and cultures—where the course is implemented. Because of the fact that the experience presented in this paper was conducted within a computer science program, future work must be done to understand how students from other disciplines receive a course that follows a similar structure to the one presented here. The way that the course is implemented in different scenarios will depend largely on the place, the students and its culture, but despite the fact that the syllabus and methodology used in a course like this might be drastically different across the world, the outcomes, abilities, and competencies that students are meant to acquire should remain the same. An additional opportunity for future work can be found in the curatorship of new bibliographies beyond or alternative to Hofstede and Vygotsky; this can contribute to shifting the course's focus, further adapting it to different cultural, disciplinary, or other contexts.

One question remains unanswered: as Tables VIII and IX show, a minority of students was not able to understand the importance of appropriating the concepts presented throughout the course. This group of students is a reflection of the diversity of reactions that the issues being presented provoke. It may be possible that these students do not accept the idea of a "multi-versal" (nonuniversal) interpretation of the world we live in. Because of this, future strategies to motivate, respect, and work with this group must be developed.

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APPENDIX B

PAPER II

Scripting For Collaborative Search Computer–Supported Classroom Activities

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Scripting For Collaborative Search Computer–Supported Classroom Activities

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Abstract— Searching online is one of the most powerful resources today's students have for accessing information. Searching in groups is a daily practice across multiple contexts; however, the tools we use for searching online do not enable collaborative practices and traditional search models consider a single user navigating online in solitary. This paper presents a three level conceptual model, called the Collaborative Search Procedural Model, which enables the implementation of collaborative search classroom activities based on multi-user collaborative search scripts/. A software solution, CollSearch, which follows the Collaborative Search Procedural Model and offers a unified tool to enable collaborative searching computer-supported classroom activities, is also presented. Empirical evaluation of the tool with high school students as part of an English as a second language course shows that students' outcomes improve when compared to non-scripted group search. Results show that by following the Collaborative Search Procedural Model students better appropriate the work they build together with their group. The OECD has highlighted the importance of collaborative work by the fact that PISA 2015 will assess collaborative problem solving; collaborative search is a fertile field for fostering better group work interactions. This paper shows that new tools that enable collaborative work dynamics in searching for information must be developed in order to address the educational challenges that today's students are facing.

Index Terms— Computers and education, collaborative computing, collaborative learning, web search

1 Introduction

1.1 Collaboration in the search task

ONE of the most common tasks carried out on the Internet is searching for information. Under a traditional model, this task is conceived as executed by a single user, omitting interaction with other people (Twidale et al., 1997). Because of this, online search tools –search engines plus the browsers used to access them- are mostly designed for users to search individually (Broder, 2002). Education, work or social interaction are some of the many scenarios under which collaboration in the search process happens in our daily lives (Amershi & Morris, 2009); however search engines and browsers cannot handle this characteristic, forcing users to turn to complimentary methods and tools. Examples of this are the use of a single computer, with one user leading the search, and another looking over his shoulder, sharing search results via email, or coordinating joint searches through instant messaging systems (Morris, 2007). The distance between the functionality offered by the technologies we use, and the practices of users searching online for information translates into processes where collaboration is not only not supported but also discouraged by the many obstacles users face when attempting to search online together.

Group information searching and the lack of tools to support it have been studied in recent years. (Amershi & Morris, 2008) identified a series of limitations that emerge when users search online for information together without tools that have been specially designed to promote collaboration. Some of these limitations are:

- Difficulties contributing. There are multiple scenarios under which current search tools foster an environment where group members asymmetrically contribute to the search task.
- Lack of awareness. Dominating group members minimize the contribution of others, reducing the awareness of their ideas and suggestions.
- Lack of hands-on learning. Group members who do not have access to a shared computer's input devices loose the opportunity to gain expertise interacting with search technologies.
- Information Loss. Multiple difficulties emerge when groups try to keep track of their findings.

These problems help shape an initial research question; how can the search process be scripted to foster collaborative practices between users when they search online together? A script structures the interaction between individuals and determines collaboration and problem solving logistics (Nussbaum et al., 2009), as well as offering detailed sets of instructions for each part of the activity being conducted (O'Donnel & Dansereau, 1992). Scripting for collaborative searching requires us to distinguish between cooperation and collaboration, as the difference

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between them is often unclear. Cooperation refers primarily to the division of tasks within a group, where each member is responsible for his own actions, while collaboration is defined as the coordinated work of a group of individuals to solve a common problem together, where all members are responsible for the end result (Roschelle & Teasley, 1995; Dillenbourg, 1999). Cooperation is similar to what factory workers do in an automobile assembly line, where each worker is responsible for carrying out a specific action, and is only worried about completing said action successfully. Collaboration, on the other hand, can be compared to putting together a puzzle, where everyone helps on any part of the puzzle and is responsible for a misplaced piece (Szewki et al., 2011) . When applying these concepts to group information search, it is possible to see how cooperative searching is actually a union of individual searches, and doesn't necessarily offer a technological challenge to the tools we use today. On the other hand, collaborative searching faces us with the need to restructure our practices and tools to include the possibility for users to search and build solutions and answers to questions together.

The success of collaborative dynamics in-group work depends on six criteria that have been established in several studies, and were summed up in the work of E. Szewkis (Szewkis et al., 2011). These collaboration criteria are:

- Common goal: a common objective, shared by all the members of the group (Dillenbourg, 1999).
- Positive interdependence: correlation between peers' work, so that the success of each member depends on the work of his teammates (Johnson & Johnson, 1999).
- Coordination and communication: interactions must occur in the right order and at the right time, avoiding the loss of communication and cooperation efforts (Raposo et al., 2001, Gutwin & Greenberg, 2004).
- Individual accountability: each member of the team is responsible before his teammates for the actions he carries out and their consequences (Johnson & Johnson, 1999).
- Awareness: each member of the group can obtain information about the state that the work is in regarding both the group work and his teammates' individual work (Zurita & Nussbaum, 2004).
- Joint rewards: depending on the results of their work, the entire team receives the same evaluation, whether it is a reward or punishment (Zagal et al., 2006).

Additionally, collaborative search presents the challenge of division of labor (the way that the members of a group distribute the workload between themselves). Attempting to reduce unnecessary redundancy users work with parallel search patterns; this can only be achieved successfully through high coordination and awareness of teamwork (Morris, 2008). Faced with this task, strategies that distribute the workload enabling parallel work without affecting awareness of what others are doing must be found.

All of this adds up to the need to develop new search models that support collaborative behaviour among users. Our initial research question can be rephrased as, how can the search process be scripted to help align a group of users under a common goal, augment their positive interdependence, contribute to better coordination and communication, reinforce individual accountability of each member of the group, help them achieve better awareness of their teammates' work and strengthen the division of labor between them when searching online together? The reformulation of the research question purposefully leaves out the criteria of joint rewards because this is external to the actual search process; the reward for a successful or unsuccessful search session depends on the context where this is being carried out and therefore does not correspond to the organic structure of the task of searching online for information.

1.2 Collaborative learning and collaborative search

In recent years, collaborative learning (CL) environments have gained importance and notoriety. By collaborating with their peers, students develop important communication and social skills as they learn to carry out multidirectional dialogues and submit their ideas to their classmates' critical analysis (Nussbaum et al., 2009). Collaborative learning allows the members of a group to articulate their points of view and negotiate and exchange ideas; learning is achieved through a process of building knowledge (Infante et al., 2010; Zurita et al., 2005) where students interact with the source of information, their peers, and the teacher.

The Internet, with its growing availability in schools, is shaping up to be the main source of information for students. A large part of the information searches that are carried out within schools are based on group interactions (Large et al., 2002), which is why searching for information has the potential to become a powerful collaborative learning activity. Collaborative search allows students to share not only the results or final products of information searching, but also the process that led to those results (Twidale et al., 1997). Cooperative searching, by merely distributing the workload, encourages bad practices where students use only a fragment of knowledge that they later copy-and-paste to form a greater project; contrarily, collaborative search moves students to work together to build, as a group, the knowledge they need. Collaborative learning environments provide a fertile field where the previously stated research question gains practical applicability; how do collaborative search activities –that follow specific scripting- change the way students work together in groups when searching for information?

Effective collaborative search activities require proposing search models and activity scripting where the user is no longer viewed as an isolated individual, but as an active member of a group. The purpose of this paper is to present a conceptual model of the process of collaborative search and the scripting it requires to be used as a structure for teaching activities that revolve around group search for information and the collaborative building of knowledge. Section 2 presents a model for collaborative search that is articulated through three levels: a high level understanding regarding the search process that each user faces (abstract model), a general structure for collaborative search activities within the classroom (Macro-Script), and finally the necessary considerations to implement the model in specific activities that fit the pedagogical objectives that the teacher wishes to reach with students (Micro-Script). Section 3 presents the CollSearch tool, a specially designed computer software that follows the Macro-Script proposed in Section 2. Section 4 presents an empirical study conducted with high school students that evaluate students' outcome when working with the CollSearch tool. Section 5 presents conclusions and future work opportunities regarding collaborative search as a collaborative learning tool.

2 Scripting for collaborative searching

The complexity of developing multiuser search models that promote collaboration among the members of a team is possibly one of the reasons that explain the lack of computational tools that help to carry out this task. In order to better understand the challenge, the problem can be divided into two levels: the user's experience when faced with the task of searching (abstract model) and the sequence of steps or stages that a collaborative search activity follows (script). Scripting can be conceived on two levels: on one hand, we have the general structure of the activities (Macro-Script), and on the other we have the concrete steps that must be followed during a collaborative search activity within the classroom (Micro-Script). A Micro-Script is an instruction manual for the teacher and the student that adapts the Macro-Script to the specific subject and context in which the activity is being carried out (Dillenbourg & Tchounikine, 2007). In order to illustrate the difference between both scripts, we can picture a game of chess. The Macro-Script contains the rules of the game that determine the existence of two players that face each other, the goal for each player, the distribution of the pieces on the board, the movements allowed for each piece, the structure of turn-taking in the game, etc. Then a Micro-Script determines the implementation of the Macro-Script. This Micro-Script changes according to the type of implementation; for example, the game can be played with a physical board and pieces, by letter, through a computer simulator, etc. While the Micro-Script can change depending on the support tools that are used and the context of the game, the Macro-Script remains constant because each Micro-Script is an implementation of a game of chess. This allows us to see the logic of the activities and their specific implementations, separately.

The following model is articulated on the three levels described above (Figure 1). It uses Kulthau's Information Search Process as an abstract model of the stages a user undergoes when facing a search task (Kuhlthau, 2010), it defines a procedural model for collaborative search and, proposes the issues that are relevant when transforming both the abstract model and the Macro-Script to a concrete implementation within the classroom, or Micro-Script.

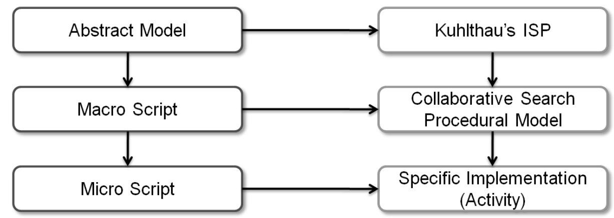

Figure 1 – Collaborative search model in three levels

2.1 Abstract model

Kulthau's Information Search Process (ISP) models the user's experience during the search task (Kuhlthau, 2010); it was initially developed in the 1980s and has been refined and updated since then, becoming a highly influential model (Cronin & Meho, 2006) that has been used across multiple settings including educational applications through guided inquiry (Kulthau et al, 2007). Despite how much the information environment has changed since the first design of the model, it remains a valid way "for describing information behavior in tasks that require knowledge construction" (Kulthau et at, 2008). The model offers a general understanding of the different stages that a person goes through during the process of searching for information. The ISP is the construction in which a user is submerged when actively seeking to understand the information found within a period of time. (Kuhlthau, 2010) describes this process in six stages:

- Initiation, when a person senses a lack of knowledge or understanding, and feelings of apprehension and uncertainty are common.
- Selection, when a general area, topic or problem is identified and the initial uncertainty gives way to a brief sensation of optimism, and a desire to begin the search.
- Exploration, when inconsistent or incompatible information is found, and uncertainty, confusion and doubt frequently increase.
- Formulation, when a focalized perspective is formed, uncertainty decreases and confidence begins to build.
- Collection, when information relevant to the focalized perspective is gathered, and uncertainty decreases while interest and involvement deepen.
- Presentation, when the search is completed with a new understanding that enables the person to explain his learning to others, or put his learning to use.

Each step of Kulthau's ISP is characterized by three domains that are relevant for the user: the feelings domain, which is directly linked to the emotions that are present at the time of the search; the thoughts domain, related to the searcher's cognitive and mental processes; and the actions domain, related to the activities carried out by the user.

Despite the fact that Kuhlthau's ISP is based on the perspective of a single person searching for information, there are studies that show that it would be possible –without major modifications- to apply this model to a group search (Hyldegard, 2009). The ISP is an abstract model that allows us to understand the process that every member of the group will go through when faced with collaborative searching. The feelings domain makes it possible for the teacher to understand the series of feelings that will overcome students when participating in a group task, and it allows to anticipate actions that will reduce the negative effects –such as the demotivation that uncertainty and frustration bring- and take advantage of the positive effects –for example, using confidence as a motivating agent. The thoughts domain makes it possible for the teacher to modify interventions at every stage to match the state of the activity, in terms of formulation of knowledge by the students, thus facilitating the process. Finally, the actions domain determines the conduct that should be promoted among students, whether it is exploration and discovery, or documentation and organization of information.

2.2 Macro-Script

In the case of collaborative search activities within a collaborative learning context, we propose a Macro-Script called *Collaborative Search Procedural Model* (CSPM). The model considers the existence of two roles: student and teacher. The student acts as a member of a search team who must collaborate with his peers, search for and contribute new information and document the search process, as well as the results. The teacher is a facilitator of the activity and must monitor each groups' and students' performance to know when and how intervention is required. This model presents the collaborative search activity scripted as a series of steps where the individual process that each student goes through –described in Kuhlthau's ISP- is inserted into a group dynamic where the collaborative atmosphere aims to take advantage of the interaction among peers, so as to reduce negative feelings –uncertainty, frustration, etc.- and boost positive feelings –optimism, confidence, etc. The CSPM proposes decreasing interventions from the teacher, as far as guiding the search process, so it is gradually left in the group's hands as they learn to focus their work. In order to achieve this, the steps that are mainly exploratory are guided by the teacher, while the steps where knowledge is built and documented call for more independent work by the students.

The CSPM's Macro-Script proposes four linear stages: (1) Motivation and domain definition, (2) Search term selection, (3) Search and construction –made up of the sub-stages of personal search, personal build, personal discover and describe, and group build- and (4) Group discover and describe. The structure of the CSPM –including stages and sub-stages- is summarized in the diagram presented in Figure 2. Each stage and sub-stage of the CSPM is defined by a high-level procedural description, by collaboration goals determined according to the criteria laid out in the introduction of this paper and by Kuhlthau's ISP (Table 1).

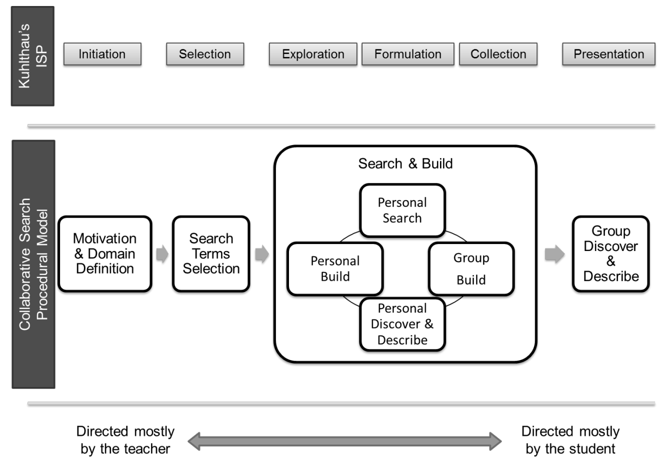

Figure 2 – Collaborative Search Procedural Model and its connection to Kuhlthau's ISP

Following the collaborative search model in Figure 2, each of the stages of the Macro-Script in Table 1 must be implemented through a specific Micro-Script. Determining these instructions requires a series of design decisions that are specific to the implementation scenarios under which the final deployment will be done; because of this, there is no unique Micro-Script for the model. The flexibility to adapt the Macro-Script to specific contexts broadens the areas of applicability of the proposed model. Some of the most relevant factors to be considered when designing Micro-Scripts for the proposed Macro-Script are:

- Technological support: In spite of the fact that it was designed with the Internet in mind, the CSPM can be implemented with several levels of technological integration that range from work that is totally based on pen, paper and books, to work that is completely assisted by computers (for example, building a dedicated software that integrates web access interfaces, as well as interfaces for the elaboration of medial hand-ins –text, presentations, video, etc.). The inclusion of technological tools especially designed with this purpose will make it possible to automate monitoring and controlling the rules in each stage.
- Formation of work teams: It has been determined that randomly selecting the members of each group, when compared to other strategies, is an effective way to achieve positive results as far as collaboration (Nussbaum et al., 2009; Zurita et al, 2005). Regarding group dynamics in order to foster better collaboration among the members of a group, it has

TABLE 1 – STAGES OF THE CSPM

Macro-Script Stage	Description	Abstract model (Kulthau's ISP) objective	Collaborative objective
Motivation and Domain Definition	The subject of the investigation, as well as its general objectives, reach and focus must be determined with the intervention of the guide (teacher). Additionally, the rules to be followed during the activity are established, such as the way in which the work will be divided, and what platform or medium will be used to build the final hand-in which could be a written document, a video, a presentation, etc.	Through a proper definition of the domain, the student's uncertainty regarding the task can be reduced.	A common goal must be established for all students. Rules of coordination and communication must be determined. The common rewards that the students will receive must be made explicit.
Search Term Selection	Lead by the activity guide (teacher) the students suggest key words or queries for the group search, which are shared with all the other students. The facilitator does a brief discussion about query construction and the search tool being used; in-group discussions about the search terms to be used are conducted to help students informally distribute the work.	Collaboration in the forming of queries accelerates their refinement, which improves the quality of the results obtained (Morris, 2008). Thanks to this, the students' optimism towards the task increases.	The collective formation of queries increases each student's awareness regarding others' work (Morris et al., 2006). By establishing an initial work distribution students can avoid redundancy and help establish each student's individual responsibility regarding the activity.
Personal Search	In this stage, each student searches for information independently –using queries related to the keywords and subdomains assigned in the previous stage. Each result must be filtered, evaluated, and valued.	In order to ensure that each student generates his own focus, confidence and sense of direction regarding the search task, the model must provide space for students to go undisturbed through each stage of the ISP. The personal stages of the Macro-Script allow each student to face the confusion, frustration and doubt that naturally emerge from the search process without pressure from the group nor distracting interactions.	Personal searches allow students to feel that part of the work belongs to them, increasing their perception of individual responsibility. By ensuring personal processes, we can avoid a single student taking over the work and ignoring others' work, which increases positive interdependence. Parallel work contributes to a distribution of the work without duplicates, while at the same time forcing an increase in awareness, coordination and communication.
Personal Build	The searching users (students) summarize every result that comes up through their web search. They are free to organize and categorize these summaries how they prefer, so they understand the specific contribution that this information makes to the investigation.		
Personal Discover and Describe	The student organizes his personal summary so it is coherent, and builds a macro-structure with the information, following the classification he determined in the personal build stage. In this way, he can articulate his ideas and knowledge before exchanging with his teammates.		
Group Build	Using the results contributed by each member, as well as their respective summaries of key concepts, the information must be reorganized, so as to articulate the entire group's contribution in a first draft of the answer to the initial question. Group building can happen through the reclassification of group summaries under new criteria defined by the group, or by linking ideas from the summaries, so as to create a "map" of the knowledge that the group has built.	Interaction among peers can dissipate doubts and confusion among group members. By coordinating each member's contribution, a focus is established and a unified sense of direction is created. Interaction among peers validates each member's ideas, so the confidence each student has regarding his work increases. Working in a group also motivates students to search for better answers. In some cases, the opposite dynamics can present themselves, where interaction among peers increases discrepancies and conflicts emerge; this is why the teacher must monitor each stage and mediate when necessary.	The integration of each member's contribution increases positive interdependence and forces students to work in a coordinated manner. Ideas presented by teammates increase awareness regarding others' work. Building a single final presentation that belongs to the entire group –as opposed to belonging to any one student- allows students to better understand why there are joint rewards.
Group Discover and Describe	The members of the group work together to build a final answer to the question that was the object of the collaborative search. This answer includes all the angles that were studied individually, but organized in such a way as to allow the group to articulate and transfer the joint knowledge. In this way, the final result belongs to the entire group, and not any individual member. The format of this answer will depend on what was initially proposed by the guide.		

been observed that small groups (2 to 4 people) allow better participation for each member, obtaining consensual solutions in the development of the investigative assignment (Valdivia & Nussbaum, 2009).
- Type and construction of the final hand-in: The search and work dynamic will be strongly influenced by the final hand-in that is required of students. The work students develop is different when it is aimed at an essay, an oral presentation, a video, etc.

3 CollSearch, a software tool based on the CSPM

The CSPM and the Micro-Script that implements it propose a schoolwork situation where a group of students can investigate a certain subject assigned by their teacher, and then collaboratively build a final hand-in. The first two stages of the CSPM, which are mostly directed by the teacher, present the topic and help students learn about query construction and search techniques. The following three stages are individual research phases, where the student finds information that is relevant to the topic, builds his own point of view and knowledge on the matter and prepares to share his results with his teammates. The final two stages allow students to exchange knowledge –fostering learning among peers- and work together to build a final hand-in containing ideas proposed by all the members of the group.

The implementation of the CSPM in a computational tool requires the elaboration of a Micro-Script that transforms each step of the previously presented Macro-Script into a concrete sequence of activities. It also requires a communication and interaction model that allows the members of each group to interact among themselves and with the system, while the teacher monitors each group's advances.

3.1 Micro-Script for CollSearch

Because the CSPM is a Macro-Script, it can be applied to many different scenarios through different Micro-Scripts. CollSearch's Micro-Script establishes a workflow that enables a group research activity within a classroom environment; each step of the Micro-Script is aimed at promoting collaboration between the group's members.

To follow the CSPM through CollSearch the following implementation decisions were made:

- The software incorporates the use of a Virtual Work Table, visible to all the members of the group as a way of establishing a common work area where each student can contribute the results of the personal search stages and collaborate during the group stages.
- In the summary of individual work (Personal Discover and Describe Stage) each student must build a small outline or conceptual map from the notes obtained during the individual search for information. This outline is shared at the Virtual Work Table.
- In the summary of group work (Group Build Stage) the students must build an outline or conceptual map where the notes from every member of the group are articulated to show all the information they found and how it is interconnected. This outline is built at the Virtual Work Table, where each member was initially working by himself.
- The final hand-in is built using the group summary outline, and it is a written report that one of the members of the group types up, with the help of his teammates.

Table 2 shows the implementation of each step of the CSPM through specific sequences of activities that compose the Micro-Script, broken down according to the two roles considered by it: teacher and student.

In order to allow some space for personalization and adaptability, some stages consider parameters (indicated in Table 2) that the teacher must adjust before beginning the activity, so its duration can be adapted and the possible reach of the investigation can be controlled. The parameters that determine the minimum number of bookmarks and notes for each student in the individual stages are aimed at making sure that all students collaborate, ensuring a proper division of the work. At the same time, the parameters that determine a minimum and maximum number of group notes aim to control the length of the final paper.

- For the proposed Micro-Script, the following rules regulate passing from one stage to the other in the sequential order proposed by the CSPM:
- In order to move on to the Group Discover and Describe stage, where the final document is created, students must comply with the minimum and maximum number of web references and notes, both individually and as a group.
- In order for the final document to be finished it must incorporate all the notes that were on the group's table when they moved on to the Group Discover and Describe stage.
- The final document will only be ready to be checked by the teacher once all the members of the group have approved it. The student assigned as the editor of the document must incorporate its group mates' feedback and do any necessary modifications until the entire group agrees on the end result.

3.2 Communication and Interaction Model

One of the complexities involved in the collaboration criteria of Coordination and Communication (Gutwin & Greenberg, 2004), and Awareness (Janssen et al, 2004) is the fact that in order to be updated regarding their teammates' work, students may be constantly interrupted in their own work; this makes it necessary to implement technological support for the CSPM that provides transparent communication mechanisms among the members of the group, i.e. mechanisms that don't interrupt the

TABLE 2 – MICRO SCRIPT FOR COLLSEARCH

CSPM Stage		Specific Micro-Script Instructions	Software Parameters
Motivation and Domain definition	Teacher	The teacher introduces the topic of the investigation, explaining its general objectives, reach, and focus. In the computer system, he defines the parameters of the activity and uploads the class list, in order to randomly form groups.	Search topic, which is made explicit in the system through general instructions.
	Student	The students interact with the teacher during the introduction of the investigation topic, just as they would during a normal class. In the computer system, each student registers and logs in (Figure 3a), waiting to be randomly assigned to a group.	
Search Term Selection	Teacher	The teacher asks students to suggest search terms that pertain to the topic. He receives the students' contributions in the computer system and might add more or delete some if necessary. The teacher must then lead a brief discussion about each search term and how they relate to the topic. Additionally, brief explanations about terms that the teacher considered off-topic (and deleted) can also be useful. During this discussion, the teacher must also address query construction techniques and how queries impact the quality of our research.	Minimum number of search terms each student must contribute. Number of search terms assigned to each student (if the assignment is done explicitly).
	Student	Students form groups, as determined by the application. The students must suggest search terms that they believe will cover the domain and focus described in the parameters of the activity. Suggestions are sent to the teacher anonymously. Once the teacher has filtered the terms, each student receives the list of them and a brief in-group discussion must be had to determine an initial work distribution within the group (Figure 3b). This can be explicit (each student is assigned specific search terms) or implicit (where students orally agree on how to distribute the work and the areas in which each one will focus).	
Personal Search	Teacher	**From this stage onwards the role of the teacher remains constant**; he monitors each group's progress using his computer interface. When he detects the need, or a group calls him, he can physically approach them and provide help or guidance.	Minimum number of bookmarks each student must create.
	Student	Each student carries out individual searches. Whenever he finds a useful site, the student can bookmark it, adding extra information like a personal description or evaluation of its contents (Figure 3c). Saved web references are available for revisiting.	
Personal Build	Student	The student can access his bookmarks and make small annotations about the information he has found (Figure 3d). Each note is a summary of the site's content, and it is stored along with the source's URL.	Minimum number of notes each student must create based on his bookmarks.
Personal Discover and Describe	Student	The student organizes the notes he has created, placing them on the Virtual Work Table (Figure 3e) in the order that makes sense to him. He can add hand-drawn pictures and edit the contents of the notes, so as to strengthen his mental outline of the content he is contributing. While the table is a space that is shared by the entire group, in this stage each collaborator works individually, using a space on the table that is separated from his teammates.	Notes from all members of the group are organized in a logical order.
Group Build	Student	Students work as a group to organize the information they collected individually. Each student checks the contents of the Virtual Work Table (Figure 3f) complementing his teammates' information with his own knowledge, with the possibility of adding comments to a teammate's notes, checking sources (web references), modifying the contents of the note or the outline. All the notes are reorganized, forming a group outline that expresses the vision and knowledge of all the members of the group.	Minimum number of notes for the group. Maximum number of notes for the group (excess notes must be eliminated through a vote).
Group Discover and Describe	Student	A writing student is randomly selected and begins to edit the final document (Figure 3g): selecting the notes from the outline, one by one, sending them to the document display and incorporating their contents in a consistent manner; references are automatically added to the paper's bibliography. During the writing process the other group members check their teammate's work and help him, mediating through different communication mechanisms (directly or through the group chat). When all notes have been used, the writer notifies his teammates that the document is ready for their evaluation. When the document is under evaluation, readers must vote on whether they agree with the result or not. When all readers agree, the stage and the activity are completed.	Length of the final essay.

student's work flow. For CollSearch we determined the communication needs that the system had to fulfill in each stage of the CSPM (Table 3). The main communication solution was providing the software with a written message chat that is always visible, so the students can communicate with their teammates at all times, without interrupting the work of their fellow group mates (Figure 4). For the individual work stages, we determined the need to create an interface that allowed access to a summary of everyone's work that could be consulted at any time, by any member of the group. For the individual and group stages, as explained before, a Virtual Work Table, where each student contributed his notes and references, was created.

4 Empirical Evaluation

To evaluate the impact that the CollSerach tool has on students' work, we conducted an experimental trial with 60 students from the eleventh grade of a private non-government supported high school in Santiago, Chile.

4.1 Method

The activity was part of an English as a second language course and asked students to write a letter to the International Olympic Committee (IOC) nominating Santiago, Chile as the host city for the 2024 Olympic Games. Students were asked to include a minimum of three of the following topics in their documents: Santiago's sports infrastructure, Santiago's hotels and accommodation infrastructure, Santiago's crime rate and safety, Santiago as a tourist attraction, Santiago's transport system, or Santiago's climate. The goal was for them to write in English a compelling argument that would convince the IOC to consider Santiago as a possible host city.

Students were randomly split into groups of 3 and then each of the 20 groups was randomly assigned to one of the following independent activities:

- Control Group: Each student was given access to a personal computer with an internet browser and word processing software. Written instructions were provided and each group was free to organize their work in whatever way they chose. The activity facilitator (teacher) conducted the introduction to the topic and an initial search term discussion (similar to the one the CSPM considers). Later during the activity, the teacher was available to answer questions and guide students through the activity if they asked for her help.
- Experimental Group: Each student was given access to a personal computer with the CollSearch tool. A week before the activity took place, students assigned to this group had an initial 90 minute introduction to the tool and worked in a preliminary activity with a completely different topic and different groups than the experimental session. This initial activity was meant to teach students how to use the CollSearch tool and control for any changes in performance between the experimental and control groups that could be explained by the fact that the CollSearch tool was unknown to students while the browser and word processing software used by the control group was not. During the experimental activity, students were given the same set of written instructions given to the control group students. The activity facilitator (teacher) was available to answer questions and guide them through the activity if they asked for her help.

Each group, experimental and control, was given 90 minutes to complete the activity and had to hand in only one letter per group. After they had done this, they had to access an online form where each student was asked to rewrite their letter according to what they remembered from their group's work; during this phase of the activity students were forbidden to interact with each other and no longer had access to the document they had built as a group. The purpose of this second part of the activity was to evaluate how much of the group work had each student appropriated by participating in the group work. An external teacher who did not know which documents belonged to the experimental or control groups conducted a blind evaluation of each of the groups' work. The evaluation measured the overall quality of the letter considering the groups' argumentation and use of facts. A second evaluation was then conducted in which the external evaluator was asked to assess how each individual letter compared to the group's letter; this was done by comparing how much of the information contained in the group's work was reflected in each individual letter. The external evaluator assigned a percentage from 0% to 100% to each individual letter according to how complete it was compared to the group's letter. This meant that any individual letter that contained as much (or more) information than the group's letter would be assigned a 100%, independent of the first evaluation that measured the overall quality of the group's letter.

4.2 Results and Discussion

Table 4 shows the results of the experimental evaluation of the group work and the comparison between the individual and group letters.

Results show a statistically significant difference between the performance of the control and experimental groups. The evaluation of the level of achievement of the activity's goals raises when students work using CollSearch instead of freely choosing their work methodology (Cohens' d=1.24). When each student's individual work is compared to their group's work, there is a drop between the amounts of information that the group incorporates into their work versus the information that each student is able to recall when working individually. Despite this being true in both groups, there is a statistically significant difference between the experimental and control groups; students who followed the CSPM script within CollSearch can individually recall more information from their group's work than students that could freely choose their group's work methodology (Cohens' d=0.63).

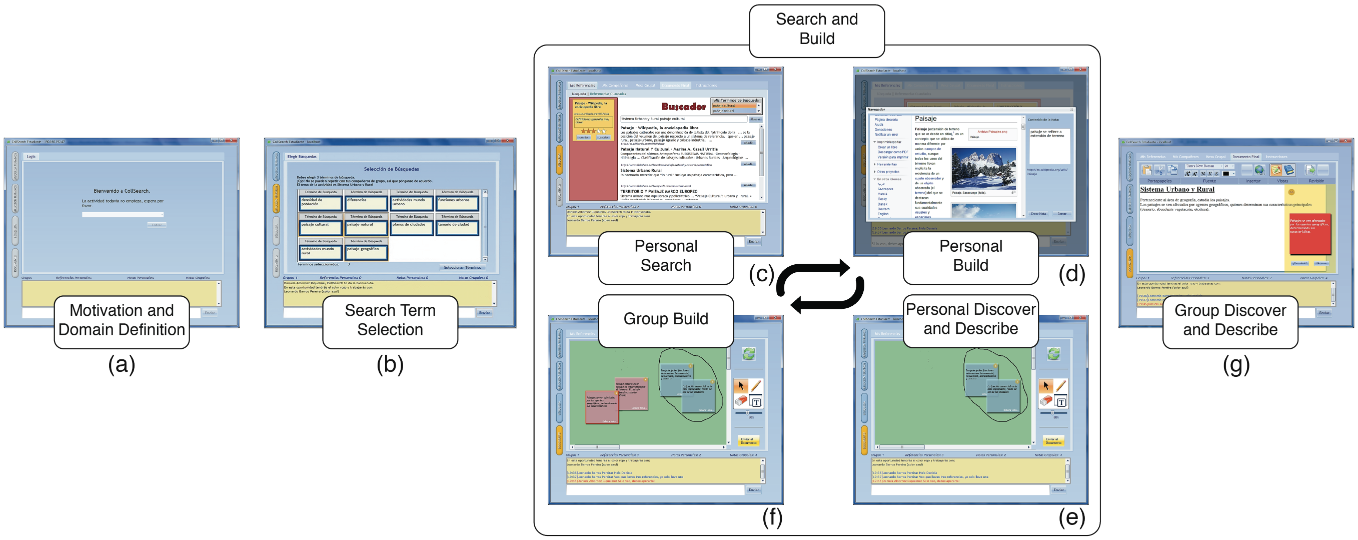

Figure 3 – CollSearch interfaces and how they follow the CSPM.

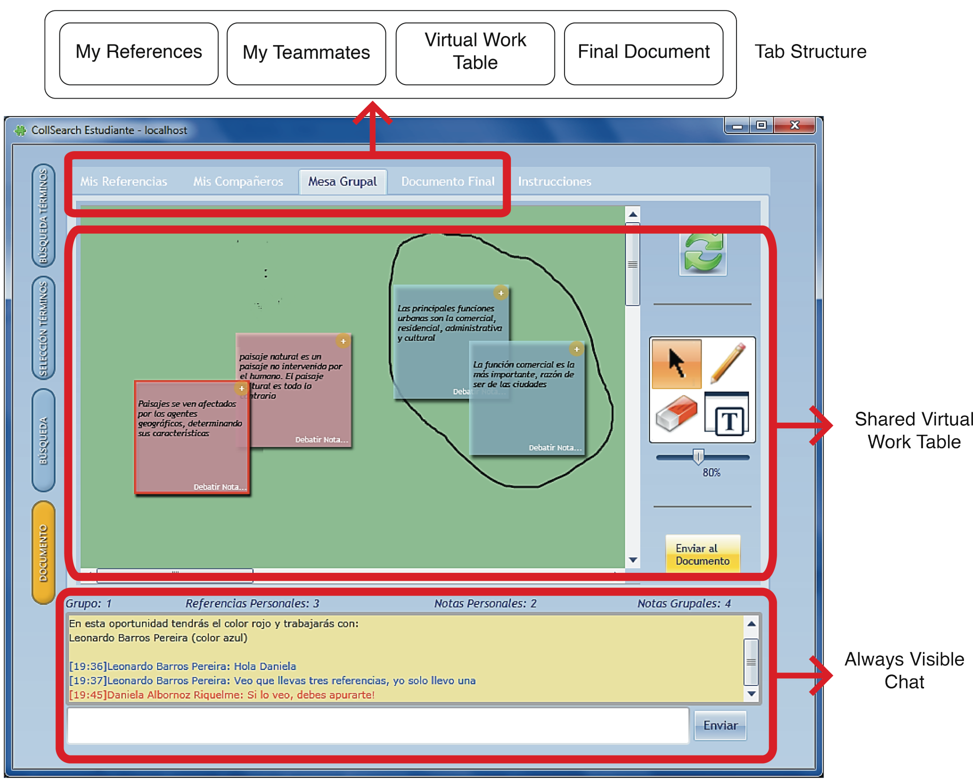

Figure 4: CollSearch's Communication Support and Tab Structure

TABLE 4 – GROUP WORK EVALUATION

	Percentage of accomplishment of the activity's objectives (p = 0.0064)	Percentage of the group work reflected in the individual work (p= 0.0087)
Control Group	87%	61%
Experimental Group	99%	77%

The differences observed between the control and experimental groups can be explained by the fact that the CSPM fosters collaboration by forcing students to be aware of their teammates' work and to build their final answers together. The activity facilitator observed that most of the students from the control group chose to work in cooperative ways in which each student was responsible for one part of the letter, and then the final document was built copying and pasting each part together; CollSearch through the CSPM prevents students from doing this by forcing them to discuss as a group their work and to build together their final document. This might also explain why students from the experimental group are able to recall more information from their group's work than students from the control group; instead of simply giving a chunk of text to their group's work, CollSearch made them be aware of their teammates' research and contribute their work in a way that appropriately fit their group's final document.

4 Conclusions and Future Work

The tools we use today to search the Internet do not offer the possibility for groups of users to work collaboratively. The articulation of Kuhlthau's ISP with the macro and Micro-Script structure proposed by the Collaborative Search Procedural Model is a first approximation to supporting collaborative search practices.

Students who face collaborative search activities while following the CSPM when compared to those who can freely determine their work methodology show better appropriation of their group's work. Empirical evaluation shows that the CSPM increases students' performance and improves the overall quality of their work. Future work must be conducted to understand the impact of systematically using CollSearch as a collaborative learning tool and to study how the observed differences change over time as students and teachers better appropriate the model. An exploration of how different Micro-Scripts and implementations of CollSearch might have bigger or smaller impacts on student performance might also provide further insight on the ways in which the CSPM can have a positive impact on collaborative learning activities. Additionally, from a technical point of view, instead of being built from scratch, new versions of CollSearch could be built using previously existing online tools mashed-up into a unified tool.

Finally, it is important to note that Collaborative Search is a scarcely explored and emerging research field; the approach followed in the project presented in this paper is one of many possible alternatives. The Program for International Student Assessment (PISA) has emphasized the importance of the collaborative component, and starting in 2015 it will measure the capacity and willingness of students to solve problems through interaction among themselves (Davidson, 2012; De Jong, 2012); because of this, we encourage the computer science research community to explore other models that promote collaboration in the search task. Additional elements that must be addressed in future work are the dangers of over-scripting (Dillenbourg, 2002). Scripts provide the necessary scaffolding to enable users to effectively collaborate, but when the overhead introduced by following specific Micro-Script instruction sets surpass the benefits of the new work dynamics, users' performance and throughput drops. Finding strategies to build effective macro and Micro-Script structures is a challenge the community must face through more empirical investigations. Future work must focus on ways to prevent over-scripting and on how to balance the need for a structure to guide activities and the need for students to be able to determine the structure of their workflow. Although this paper presents empirical evaluation conducted with high school students, there are multiple educational settings in which collaborative search can prove useful to improve student outcomes; the use of CollSearch and the CSPM in academic and university settings provides a fertile field to explore in future work.

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APPENDIX C

PAPER III

Interactive films and coconstruction

Verdugo, R., Nussbaum, M., Corro, P., Nuñez, P., & Navarrete, P.

Interactive Films and Coconstruction

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Interactive Filmmaking is both an aesthetic and technological challenge. Steerable plots, where audiences are not passive viewers but active participants of the narrative experience, require an engaging narrative model as well as a technologically feasible structure. This article discusses the connection between aesthetics, cinema, and interactivity and presents a model for interactive narration that is based on the audience's ability to read and interpret footage differently according to its context. Through a detour narrative model it is possible to engage audiences in a coconstructive hypermedia experience while at the same time minimizing the amount of footage required. An interface model that allows seamless hypervideo navigation through graphic interaction is also discussed, and the interactive short film *The Crime or Revenge of Fernando Moreno* is presented, along with user experience and usability studies that experimentally prove our hypothesis.

Categories and Subject Descriptors: H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Video*; H.5.4 [**Information Interfaces and Presentation**]: Hypertext/Hypermedia—*Architectures, navigation, user issues*

General Terms: Design, Experimentation, Human Factors

Additional Key Words and Phrases: Interactive film, coconstruction, storytelling, filmmaking

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1. INTRODUCTION

For every script ever written, many alternative stories have been left out. When commenting on a film we often hear people say, "What would have happened if..." Immediately after, they imaginarily rewrite the script, provide different endings, and change the course of events. Conventional films conceive audiences as passive receptors of a fixed stream of images, and watching a movie twice means sitting through the same stream again. But what would happen if movies, instead of being static repetitions, became aware of the audience and incorporated it into the unfolding of the plot? Stanley Kubrick once said, "If it can be written or thought, it can be filmed" [Halliwell 1988], so why not explore those stories that are being left untold, and let the audience decide what is to happen next? Exploring

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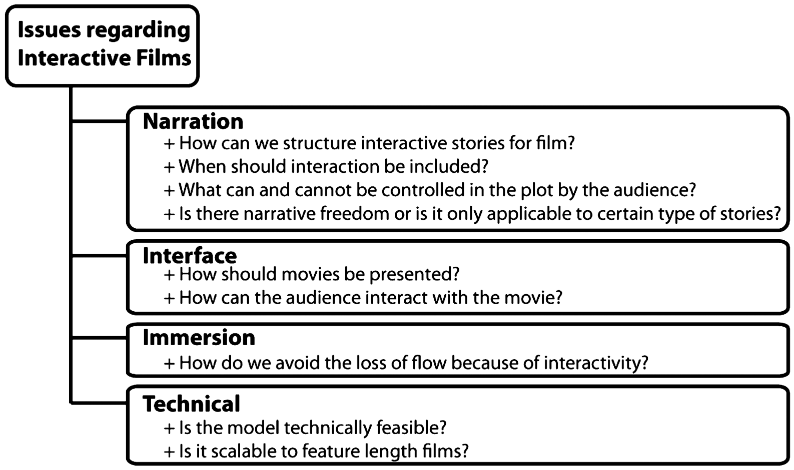


Fig. 1. Issues regarding interactive films.

the narrative hidden behind a “What would have happened if...” is both a technological and artistic challenge. Interactive filmmaking requires the creation of an aesthetically engaging experience along with a technologically feasible structure, hence the double nature of the problem. To consider only the aesthetic potential of interactive storytelling, without its technological aspects, results in a purely theoretical discussion, while approaching the problem exclusively from a programmer’s point of view creates a system that does not catch the audience’s interest. Interactive audiovisual narratives must respond to many challenges, of diverse natures including narration, interface, immersion, and technical implementation (Figure 1).

In this article we describe our approach towards Interactive Filmmaking. Our aim is to present an authoring model to structure interactive films that considers audience participation as a pivotal component of the narrative act, along with the interface model required to provide a seamless way of navigation through the “steerable” plots of these audiovisual experiences. We begin by presenting related work in the field, and then analyze the connection between aesthetics, cinema, and interactivity throughout history. We then discuss the narrative model that allows us to create authorial content that, while still allowing authors to have narrative control, allows spectators to have an effect over the unfolding of the plot. We also present the concept of coconstruction, which enables us to conceive the story as an act of cocreation between filmmaker and viewer. We explain how coconstruction enables the building of different stories, based on the viewer’s ability to read and reinterpret scenes in different ways, according to interactively changeable contexts to those scenes, and explain why this is not only an aesthetic need but also a technological and economical issue. Results of a narrative experiment conducted with high school students are presented, to provide an empirical understanding of coconstruction. We then discuss our interface and presentation model, where hyperlink between one video and the next is available during a specified time window, and the interaction occurs visually in the form of dragging and dropping elements into or out of the film. We then conclude with the experimental interactive film *The Crime or Revenge of Fernando Moreno*, where our narrative model, the concept of co-construction and our ideas regarding interface have been implemented. A survey that measured the system’s usability, the audience’s reception of the film, and the assessment of co-construction as a relevant part of the storytelling was conducted, and the results, along with an analysis, are also presented in the final section of this paper.

2. RELATED WORK

Interactive video has been thoroughly discussed and many different yet complementary definitions can be found. From a general point of view, “A video application is interactive if the user affects the flow of the video and that influence, in turn, affects the user’s future choices” [Stenzler and Eckert 1996], while from a purely computational point of view, “An interactive video is a digital video with hyperlink type of interaction for browsing” [Xu et al. 2003].

Regarding interactive video as a narrative tool, the broadest classification is the one presented by Handler [2008]: “all interactive movies fall into one of two quite different categories. One type is designed for a large theatre screen and is usually intended to be a group experience. The other type is for a small screen and is viewed at home. It is a much more intimate experience, meant to be enjoyed by a single individual.” An example of the first type of interactive film, designed as a collective and democratic experience, is *Terminal Time*, by Michael Mateas [Domike et al. 2002]. Our approach, which belongs in the second category of interactive films, is carried out through individual audiovisual experiences, so that the user is the sole controller of the interactive event.

Attempts to use interactive video in narrative forms have had different levels of success, independently of whether they are designed as large or small screen experiences. Many of these systems rely on complex hardware solutions (multiple screens, touch surfaces, etc.) [Tokuhisa et al. 2005; Knoller 2005; Lew 2004; Atkinson 2008] rather than on theoretical models or structures that are flexible enough to provide narrative freedom. Other works, like *Interactive Drama* [Szillas 2005], limit the user’s interaction to one character, and resemble a role-playing video game while others limit the interaction to one user who performs in front of an audience [Márquez et al. 2007].

The experimental hypermedia prototype *HyperCafe* [Sawhney et al. 1996] based its storytelling on different conversations happening at the same time, providing users with the option to move from table to table overhearing one conversation at a time while the others went on. This work also attempted to provide a general framework for hypervideo. It described different types of link opportunities, and provided different connections between videos, but was still aimed at one particular project, and not at developing interactive films as a new audiovisual language. This approach, where the system acts as a sequencer of previously edited chunks of video, is an example of a model for interactive storytelling that provides narrative freedom while still keeping the system technologically feasible. As noted by Brooks [1996] “a storytelling system is not a magic box which creatively makes up a story when asked, but a system of specially stored and organized narrative elements which the computer retrieves and assembles according to some expressed form of narration.” In these cases, “the role of the computer is then to match the desire of the audience (as expressed through an interface) to an appropriate selection of content” [Davenport 2002].

Regarding the narrative potential that interactive films have, one must not forget the impact that interaction has over the viewer’s “immersion” in the story. This has been previously discussed in “flow principle in interactivity” [Polaine 2005] where it is argued that interaction is the opposite of narration. The cost of including interactivity in films cannot be the loss of flow [Csikszentmihalyi 1990]. The way to include user participation within the interactive experience must be determined with this in mind, and the user’s immersion must be considered as a key component of the overall experience. This issue involves both the dramatic flow of the stories being told [Macfadyen et al. 2007] and the interface through which users interact with the system [Johnson 2008].

3. AESTHETICS, CINEMA, AND INTERACTIVITY

The understanding of interactivity as a relevant topic for artistic production can be first found in the conscience of reception described by some aesthetic theories of the 20^{th} century [Jauss 1982]. To

Jauss [1982] and Vattimo [1997], for example, reception is ultimately the only truth of the artistic event [Perniola 2001] and therefore it is impossible to consider a work of art or creation without its encounter and interaction with an audience or spectator. Interactivity, before it had the potential to become a pragmatic fusion between art and technology, was related with the interest of artists and audiences to progress towards open works of art, where meaning and sense were not fully provided but rather left to audiences' interpretation and reading. This phenomenon has been studied and inventoried by Eco [1989] in his book *The Open Work*, where he describes texts as fields of meaning, open for reinterpretation and contextualization. Dorfles [1984] presents the idea of "interval" as a space for the structural understanding of an artistic creation through the reconstruction of the viewer's own conscience, perceptual memory and sense of time and space. These theories can all be understood as early stages of audience involvement with works of art.

In cinema, understood as both a form of mass media and a technically based channel of artistic expression, it is possible to find different levels of sympathetic relations between film and audience that go from passive contemplation to ingenious technical and narrative operations that provide higher levels of viewer immersion and interaction. A film's relation and connection with its viewers derive from the illusion of reality it provides, and the first linguistic device it has to relate with interactivity is montage. This allows creators to play with the structure of the film, to choose what will be shown and what will be hidden, to use the suggestive power of ellipsis and ultimately determine where viewers will have to fill in the blanks and make up their own story.

Technical procedures opposite to montage may also provide forms of interactivity: temporal continuity and spatial continuity. A sequence shot (the uncut following of an action by a moving camera) as used by Rosellini, De Sica, and Italian neorealism in general, was interpreted by André Bazin as a gesture of openness towards freedom of discernment, freedom of the spectator's attention, and a form of dynamic sensory realism. The same author noted that in Orson Welles's films, the use of an extensive depth of field (portion of a scene that appears in sharp focus) was an invitation so that viewers would travel through the image, and freely relate the elements that coexist, whether they remain static or in movement, within an extensive space.

Another way of interactive immersion is achieved in cinema through the use of the offscreen space, and the camera's position. What is called the "fourth wall" in theatre can be used with interactive purposes in cinema, as in *Rashomon* (1950) by Akira Kurosawa and *Lady in the Lake* (1947) by Robert Montgomery. In Kurosawa's film, a masterpiece considered as the maximum expression of offscreen space, the camera's position identifies with the point of view of judges that listen to different versions of a criminal event. Because of its open ending, where no particular version is revealed as the truth, the identification between the judges and the audience occurs in the form of an endless discussion about the final deliberation, and the determination of what really happened. In Montgomery's film all of the action is viewed through the main character's eyes, and the movement of the character determines the movement of the camera. The audience is invited to view and feel the story just like the character does, and the action is followed only through immersion with him. In films like *A Bout de Souffle* (1960) by Godard, and *Funny Games* (1997) by Michael Haneke, interaction was achieved by looking into the camera, ignoring the "fourth wall" and talking directly to the viewer. Split-screen narratives, like *Timecode* (2000) by Mike Figgis, and *Pillow Book* (1996) by Peter Greenaway, also provide ways of interaction by the presentation of simultaneous actions. Interactivity is, in these cases, reduced to the itinerary of the viewer's attention, which must jump from one space to another.

These connections between film and audience are only the surface of the interactive phenomenon, as they still maintain clear distances between the audience and the object of contemplation. Under this sympathetic understanding of interactivity, the work is perceived by the audience as autonomous, independent, and finished. It requires perspective and distance, therefore eliminating the viewer's ability to manipulate or change the work of art in concrete ways. This leads to the conclusion that interactivity can be understood in two ways:

(1) Contemplative artistic reception (reading and reinterpretation)—present in traditional films as shown in the examples above.
(2) Participative artistic reception (cocreation)—active involvement of the audience and ultimate goal of an interactive filmic experience.

Conceiving art in participative and cocreative forms implies a radical suppression of the distances between artist, work, and audience. It requires restructuring the work of art, planning specific spaces for audiences' intervention and eliminating traditional hierarchies. It is a form of cultural industry, and its product is a form of mass culture that requires and legitimizes a crowd that, as illustrated by Canetti [1984], wants to bring everything closer, suppress distances, and eliminate marginalizations.

It is undoubtedly true that interactivity in traditional filmmaking has not been explored to its full potential, and that with the digitalization of cinema and its transposition to computers and software, it is now possible to create a radical transformation of interactivity, where users can determine the plot through actual intervention of the film (participative artistic reception). Regarding this interactive potential, the focus must be put on the decisions that must be made, how these affect the impediments that our heroes are confronted with, and how they face these challenges. The impediments within the story are motivations towards freedom; the story perpetuates itself because the hero chooses. According to Roland Barthes, within the hero's freedom is hidden the survival of the story; in interactive films the hero is more exposed, and he sacrifices his liberty in favor of the opportunity to include the viewer in his deliberations and choices. The final result is not only a participative and co-creating viewer, but also a mutual codependence between the story and its audience.

4. INTERACTIVE MODELS: FROM A BRANCHING NARRATIVE TO A DETOUR NARRATIVE

One of the main problems with labeling a system as interactive is that the criteria to determine if it possesses said quality is very broad, vague, and most of all, subjective. Regarding video, one could argue that traditional playback options (play, pause, forward, rewind) along with random access (like scene selection in DVDs) are enough to consider a system as interactive. At the same time, a hypothetical interactive drama system where users could freely determine what is to happen next within the plot is unarguably an interactive system as well. Also, as exposed before, certain interactive behaviors can be identified within traditional films. So, how much interaction does it take to transition from films to interactive films? There are no definitive answers and, since we are exploring the early stages of development of interactive films, all approaches towards it are likely to change in time, as more research and experimentation is done.

The first idea that comes to mind when facing the possibility of interactive films is total freedom. In other words, we picture unlimited interactivity, where users have absolute autonomy to do as they like and conduct the plot as they wish. A system that allows such level of personalization obviously remains in the sci-fi realm and is still far from today's technological reality, but imagining it allows us to reach a very important conclusion: In such a system we would no longer need a script, therefore we could no longer tell a specific story. This proves that "interactivity is the opposite of narration" [Polaine 2005] because if we lose the storytelling ability, it is no longer a narrative act.

Knowing that interaction must be limited in order to maintain the narrative aspects of filmmaking, we have considered two narrative models used in video game storytelling: branching narrative and string of pearls. The branching narrative model is based on turning points within the script that branch the game/film into two different stories. In this model, players/viewers 'chose from pre-designed narrative paths' [Brand and Knight 2005] allowing them to have an effect over the plot, while at the

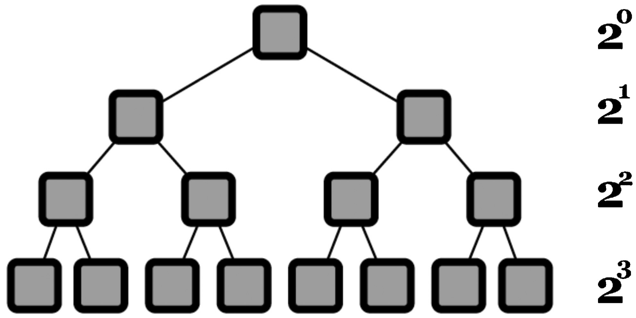


Fig. 2. Branching narrative.

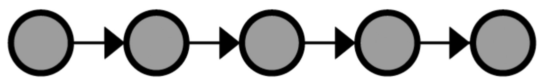


Fig. 3. String of pearls.

same time allowing writers to tell particular stories. The problem is that the number of different stories grows exponentially (Figure 2), which is the origin of a technical limitation, because the effort and resources required to write, and later produce such a film would sooner or later become unattainable. Even if this technical limitation was solved, a bigger, aesthetic limitation would remain because "narrative works are usually concerned with immersing the reader or audience in the story and the narrative suffers when interaction is simply grafted onto it. Either the characters become flat because they are repetitive, pre-recorded elements triggered by the user or because they are capable of acting in so many different ways (corresponding to interactive options) that they cease to have character." [Polaine 2005].

Whenever we attempted to write branching narrative scripts we always hit a roadblock: either the original story had changed so much that it was no longer aesthetically appealing, or the script was so big that it was no longer a single script, but rather a collection of different scripts with the same beginning and radically different endings. Filming them would have been the equivalent of filming many movies at the same time.

After facing this problem we were determined to find a model that would allow us to tell different stories while at the same time providing us with a structure where branches would not grow exponentially every time viewers interacted with the system, but rather have common paths that would allow different versions of the story to have shared footage. The string of pearls model used in video games (Figure 3) considers the story to be composed by a "series of pre-set events" [Brand and Knight 2005] that are structured linearly (in Figure 3 represented by the arrows), and different worlds that can be explored (in Figure 3 represented by the pearls or circles). In video games, "each of the "pearls" is a world, and players are able to move freely inside each of them. But in order to progress in the story, the player must first successfully perform certain tasks" [Handler 2008]. Although the freedom to explore controlled worlds is desirable in video games, it presents a narrative problem in interactive filmmaking. As with the total freedom problem described before, each pearl in this model becomes incontrollable from the writer's perspective, and the ability to tell a specific story within them is lost.

Therefore, the problem is that branching narrative allows writers to control the stories being told, but the tree structure of the scripts grows exponentially every time the story branches out, while on the other hand, string of pearls allows stories to follow a fixed and controlled path of events, but does not provide authors with proper control of the narrative process in the different worlds that can be explored. By mixing both structures it is possible to solve these problems, while keeping the benefits

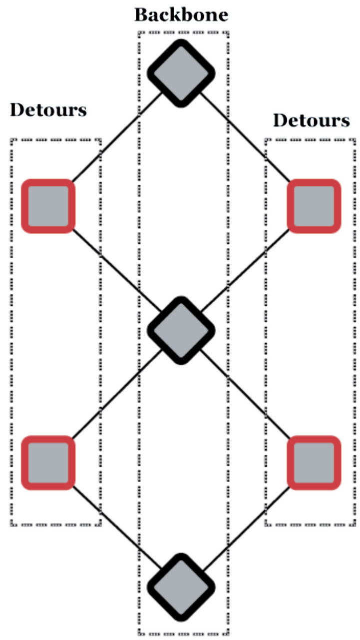


Fig. 4. Detour narrative.

that each model provides. We have called this new model, a fusion between branching narrative and string of pearls, *detour narrative*. This model has a backbone of common events that—no matter what story is told—remains unchanged, and is always seen by the audience (similar to the pre-set events in the string of pearls model). At the end of each of these backbone events viewers can interact with the system and detour from the events in the backbone to different actions, determined by their input. Here each pearl, instead of being a freely explorable world, consists of a branching narrative that branches only once, and therefore eliminates the exponential growth of the tree. After the detour is over, the system navigates back to the following backbone event. The structure of this detour narrative model can be seen in Figure 4.

5. COCONSTRUCTION

5.1 Using Context as a Tool for Coconstruction between Audience and Author

The main benefit of detours is that they can have great effects over the plot, while at the same time following a similar path of scenes, independent of the branch that is chosen. Instead of basing the different stories on different footage (as in the branching narrative model), we believe that it is possible to provide different contextualization to scenes (the detours), and that this will lead to different interpretations or readings. Our inspiration comes from the analysis of works of art, and the different ways they may be perceived, according to the information or context that one has. Consider for example Vermeer's *Mistress and Maid* (Figure 5). Try to imagine the story behind this very simple scene, where a woman is interrupted by her maid, carrying a letter. How would that story you just invented change if you knew the woman was having a secret affair? Or if you knew her husband was overseas at war?

The idea behind this is the distinction between internal and external context [Nack 2003]. External context corresponds to the information we have about the painting, its environment, the elements depicted in it, and all other structural elements regarding its content, while the internal context "enables

Fig. 5. Mistress and Maid by Johannes Vermeer. (©The Frick Collection).

the perceiver to emphasize, interpret and evaluate the sources based on the comparison with existing memory structures (The inner world model)." [Nack 2003]. External and internal context are related to each other through the fact that the internal context will be changed by the external context when the viewer reacts to the work of art (a painting, a film, etc.). Reading and interpretation will take elements from the external context and analyze them from the viewer's own internal context, which means that the sense making and final interpretation happen on the viewer's side, and cannot be fully determined by the images provided to the audience. We believe that this process has not been fully explored as a tool for creative and narrative experiences because, as noted by Nack [2003], "experiential systems usually operate in and on the external context whereas the inner context, which forms the essential aspect of the experience making process, namely the evaluation and instantiation, is hardly ever modeled."

Our coconstructive model of storytelling bases its narrative on the way we structure the external context, so that we can influence and control the ways in which the internal context will understand and make sense of the scenes of the film. By interactively determining a scene's context we can provide different contextualization to the backbone events within the plot and, through these changes in the external context of the film, have an effect over the way that the main events are interpreted and read. This allows us to play with the surroundings of the backbone events without having to change them directly. Suppose that Vermeer's *Mistress and Maid* was our backbone event, and we wanted to tell two different stories based on it, without the need of having two different paintings (Figure 6). In one story the woman has a secret affair (Context A), and in the other her husband is overseas at war (Context

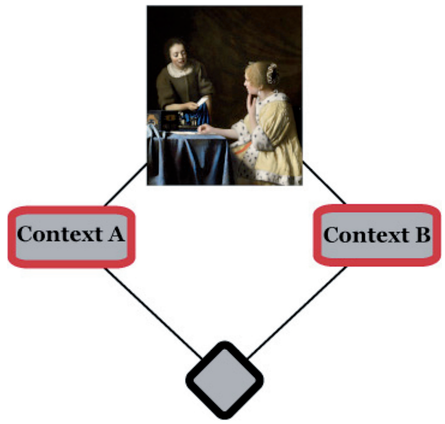


Fig. 6. Example of coconstruction.

B). These two stories could be told using coconstruction, by offering two different contexts during the detour that comes after the showing of the painting,. After viewing the painting, not really knowing what the letter meant or how it affected the story, the audience is given either context, and depending on what they see their inner context will interpret the scene of the painting differently.

When compared to a branching narrative tree that grows exponentially, it is possible to see that detour narrative, using coconstruction, allows us to control and diminish the need for shooting additional scenes, by relying on the fact that the meaning and relevance of each scene is not embedded into the film, but rather interpreted through dialogue between audience and plot. If we look backwards in time and search among the multiple stories and narrative experiences we have had throughout our lives, we quickly notice that coconstruction is difficult to apply, and in some cases, impossible. This is because our culture is lineal; we see everything through the prism of history, where things can only happen once, and out of all the possible outcomes, just one occurs. In fiction, mutually exclusive events have been banished because we always commit to one particular option. This illustrates the fact that our model of interactive films is a cultural construction that requires writers to conceive new stories in new ways, that break the old mold. We propose actively using audiences as writers that, through interaction, not only determine what scene is to be shown next, but also interpret these scenes differently according to their own reading.

5.2 Empirical Experimentation with Coconstruction

The main idea behind the concept of coconstruction is the fact that images, scenes, or even entire films depend not only on the contents depicted, but also on a viewer that reads them and builds a story with them. In a way, what it ultimately means is that, as narrators or storytellers, we can control only part of the narrative process, namely, content distribution, but regarding interpretation, we can only guide audiences into what the meaning behind that content is. Our model of interactive storytelling, by becoming aware that everything we show to a viewer will ultimately be deconstructed and then reconstructed again, tries to influence the way the audience interprets the scenes that are shown to them.

To have a further understanding of the way co-construction works and how it could be used as a tool in the script writing of interactive narrative experiences, we developed an experiment to study the effect that context and interpretation has over the stories that are built from a given content. We created 4 images (seen in Figure 7) that were used as the “content” we provided, so that participants could arrange them in any sequence and then tell a story based on them. The images show two

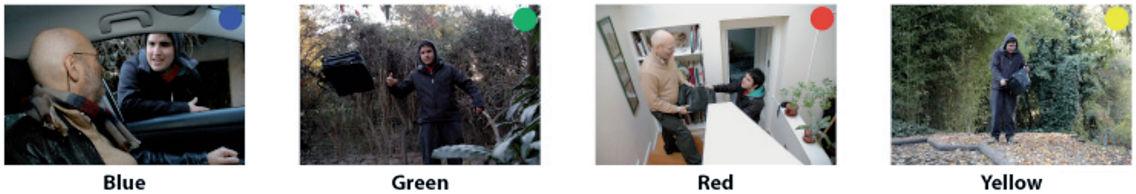


Fig. 7. Pictures of our coconstruction experiment.

Table I. Coconstruction Experiment Results

	Position of the "blue" image				
Main situation	1st	2nd	3rd	4th	**Total**
"Someone asks another person for a favor"	12	1	1	1	**15**
"Someone looses something"	3	0	1	1	**5**
"An object should be inside the black bag, but isn't"	3	2	1	8	**14**
Other	3	2	0	0	**5**
Total Stories	**21**	**5**	**3**	**10**	39

characters in different scenarios either using or exchanging a black bag. The black bag appears in three of the four images, and the objective of the study was to see how the image that does not show the black bag (the one with the "Blue" identifier) was differently contextualized and interpreted according to the position it had in the sequence the participants determined.

5.2.1 *Methodology.* 48 freshman-year high school students participated in the experiment. Each student was given the set of 4 pictures seen in Figure 7. Every student received the images in a random order, and they were identified by the colored dot on the upper-right hand corner of each image. The random order and color identifiers (instead of letters or numbers) were used so that the images had no predetermined order. The students were then given sheets of paper with the following instructions: "Arrange the images in any sequence you wish. Write down the sequence and then, based on the images in the sequence you chose, tell a story explaining what happened." No further instructions were provided; there was no time or space constraint, and participants were not allowed to talk to each other during the experiment.

5.2.2 *Results.* A reviewer read each story and eliminated 9 that were either illogical or departed so much from what is shown in the pictures, that it made it hard to identify the presence of each image in the story. The 39 remaining samples where then classified according to the main situation described in the story, and also according to the position of the image with the blue identifier (Table I).

Every story was reread and the parts that referenced the blue image were identified. Every sentence or group of sentences was catalogued according to the function it served to the story being told. In 19 of the 21 stories where the blue image is in the first position, it is used to define a situation in which the black bag will be either eliminated, thrown away, or hidden; in these stories the blue image is fundamental to understand what will happen to the bag, and why the characters must get rid of it. In all 5 stories where the blue image is in the second position, it is impossible to distinguish when the story is referencing the picture that is left in the first position, from when it references the blue image; all the participants of the experiment that left the blue image in the second position merged the actions that happened in this picture with whatever image they put in the first position. In 2 of the 3 cases where the blue image is put in the third position, the image is used to explain what was inside of the black bag and why it is important to recover it. Finally, in 9 of the 10 stories with the blue image in the last position, the image is used to explain the motivations or the drive that lead the characters to get rid of, or recover the black bag. In a way, these stories follow a very similar path to the majority of those in which the blue image is in the first position except for the fact that, when located in the last position, the blue image acts as a revelation or final surprise, while when it is used in the first position, it serves as a preparation of the scenario where the action will unfold.

5.2.3 *Analysis.* There are three important observations regarding this experiment.

(1) Despite the narrative freedom given to participants, the number of stories was not infinite, but rather limited. The vast majority of participants told one of three basic stories.
(2) Despite the random order in which the images where handed out and the fact that there was no identifiable predetermined sequence, the blue image appears -in the majority of cases, in the first or last position.
(3) According to its position within the sequence, the blue image serves a specific narrative purpose.

Regarding coconstruction, it is possible to enunciate three important conclusions from these experimental observations.

(1) From a given set of images, scenes, or footage, the vast majority of the audience will coconstruct a limited number of stories. While it is true that different people interpret and read the contents given to them in different ways, it is also true that the final result is not an infinite array of radically different stories, but rather a limited number of stories with slight differences between one another. The implications this has over interactive filmmaking is the fact that we can potentially control and influence what those stories are and, by means of understanding what audiences see according to the context given to a particular scene, it is possible to use the same footage within different stories.
(2) Being able to tell two or more stories from a limited set of images or footage does not depend on radical changes and completely different structures, but rather on slight differences and small changes in the context in which a certain scene is presented. Despite the fact that the images in our experiment could be arranged in 24 different sequences, almost 80% of participants used the same 7 sequences. This shows that the different stories we can potentially tell are hidden behind subtle changes in the way we read actions or events, and not behind complex and intricate structures that, in cinema, would potentially lead to unattainable footage requirements, along with a much more complicated narrative model.
(3) If a single image, scene, or footage can serve various narrative purposes depending on its context, then, instead of basing our interactive films on different rewritings of actions that can serve as "alternative" scenes for one another, we must think of ways to repurpose a particular action in a way that it can tell two different stories based on the same footage; basically, coconstruction enables us to change the semantics, without having to change the syntax of a scene.

6. ELEMENTS AND COMPONENTS OF INTERACTIVE FILMS

What changes must be done to the structure of films so that we can allow users to navigate the interconnected paths of a detour narrative? How can we model our Interactive Films, so that they can be easily written, produced, and then virtually played back, allowing user interaction? How can we present the film to audiences, allowing them to interact with the film, without having to stop the movie and ask them what is to happen next? We have divided the answers to these questions into two groups: Structural Issues and Interface Issues.

6.1 The Structure of the Film

6.1.1 *Microcores (MC), Scenes, and Sequences.* Within regular films, a *scene* is considered to be a succession of shots that happen within the same set, location or space. A *sequence* can be defined as

Fig. 8. Screen.

a succession of related shots or scenes developing a single subject or phase of the story, forming a distinct narrative unit. When faced with the necessity to include interactivity within the script, we realized that none of these structural elements of traditional films would help us define the basic structural unit of Interactive Films. We called this unit Microcore (MC) and defined it as. The shot, or series of shots, that contain the lineal fragment of film that shows either a backbone event, or a detour event within the plot.

According to this definition, the film is composed of two distinct units: Backbone Microcores (BBMC) and Detour Microcores (DTMC). The distinction between them is that a BBMC links to multiple DTMC, and the user must navigate to one of them, while DTMC link exclusively to the next BBMC. In terms of interactivity, BBMC are interactive, while DTMC are not.

Note that the definition purposely uses the term shot, and not scene or sequence, because depending on how much interaction is put into the script, the following duality can occur: a Micro-Core can contain a series of sequences or scenes, while alternatively a sequence or scene can contain a series of Micro-Cores. By allowing flexible relations between traditional film structure and Interactive Film structure, the model is considerably more expandable and general.

6.1.2 *Interactive Moment (IM).* Our model considers films to be composed by many Backbone Micro-Cores that link to multiple Detour Micro-Cores, that then link back to another Backbone Micro-Core. Between a BBMC and a DTMC there is a navigation point where the user's input determines what DTMC is shown next. For this purpose we have defined an *Interactive Moment* (IM) as. The place within the script where it has been stipulated that, during a specified time window, the user's input can be received. It is always located within a Backbone Microcore and is composed by: A decision that must be made by the viewer, the different options he/she has and finally, the Detour Micro-Core to be shown next, according to each option.

Detour Micro-Cores do not have Interactive Moments, because once they are over, they navigate to a particular Backbone Micro-Core and no options are given to the user.

6.2 Display and Interface

6.2.1 *Screen.* Displaying interactivity is not only a conceptual issue, but also an aesthetic one. Therefore, we propose a model that easily adapts to different filmic styles, and does not limit artists' full creative potential. We divided the screen into two distinct areas (Figure 8) and created a system of overlaying objects that are placed on top of the video. The areas are "possible action space," and "action space," while dynamic objects and static objects compose the overlaying objects that appear on top of the screen.

6.2.1.1 *Action Space.* The action space is the part of the screen where the movie is shown.

Fig. 9. Action space, possible action space, and a dynamic object.

6.2.1.2 *Possible Action Space.* The possible action space is a border that surrounds the action space, where different objects allow users to have an effect over what is shown in the action space.

6.2.1.3 *Dynamic Objects.* Dynamic objects are images that are overlaid on the screen and can be dragged and dropped by the user, within both the action space and the possible action space. According to the position where these are left, logical conditions determine the user's semantic action.

6.2.1.4 *Static Objects.* Static objects are images overlaid on the screen into a fixed position. They cannot be moved, but they may be used as buttons or drop areas for Dynamic Objects.

6.3 Example

Consider Figure 9, where we can identify the action space (two men talking), and the possible action space (the black border with the shotgun). Suppose we have reached an Interactive Moment within this Backbone Micro-Core: the two characters are having a fight, and the one wearing the white shirt says "If I had a gun I'd kill you." Immediately afterwards, the shotgun appears underneath the scene (Figure 9), in the possible action space. During a specified time window, determined by the Interactive Moment, the shotgun is available as a dynamic object. Users can drag the shotgun anywhere around the screen, and hand it to the character, or not. After the time window is over, the following Boolean condition is determined:

If (shotgun's final position == action space)
  Go To Detour Micro-Core 'Shooting'
Else
  Go To Detour Micro-Core 'Not Shooting'

With this logical condition, we are able to determine if the user has decided whether the man should have the shotgun or not, and what DTMC should be played next. If the user does not move the shotgun, the final position of the gun is the original one, which means the condition is false, and the object is not included into the action. This shows that there is a default path, because even if the user does nothing, a decision has still been made. The main benefit of this particular form of interface is that the movie never stops to receive the user's input. Instead of stopping the movie and asking the viewer "Do you want to give the shotgun to the man in white?", we have done this dynamically. Without losing immersion or flow, users can interact with the system, while the action continues to unfold.

7. AN EXAMPLE OF IMPLEMENTATION OF DETOUR NARRATIVE WITH COCONSTRUCTION

In order to test the concepts related to coconstruction and detour narrative, we called on an interdisciplinary team of engineers, filmmakers, visual artists, writers, and producers. We presented them with the detour narrative model and coconstruction, and began to work with them on our first interactive short film. Our main goal was to show how interactivity could be achieved, without the need of exponentially growing branching narrative structures, and how certain Backbone Micro-Cores could be differently interpreted by allowing viewers to change the context of certain scenes. The interactive film that resulted from this experience is available at: http://cineinteractivo.ing.puc.cl.

7.1 Fernando Moreno's Crime or Revenge: An Interactive Short Film

Fernando Moreno's Crime or Revenge is the story of a man, Fernando Moreno, who travels to an isolated countryside. With a rifle on the backseat of his old Chevy pickup, he drives fast and determined. As clear as the thick track of dust he raises behind his path, Fernando has one goal on his mind: to find the man he is looking for, and kill him. He might be a justice enforcer, or a hired assassin; a family man forced to commit a crime, or a merciless avenger. Fernando Moreno's reasons to kill, his intentions, and his fate at the end of the story, are in the audience's hands, and they will be the result of the interactive decisions they make during the film and the way they coconstruct the story beyond the script.

7.2 Constructing the Film: Considering Audiovisual and Script Issues

We began by establishing the title of the film: *Fernando Moreno's Crime or Revenge*. The title acts as a domain definition; we are telling two different stories and, thanks to interactive participation, the audience can navigate either one of them. If this were a traditional film, it would be called either *Fernando Moreno's Crime* or *Fernando Moreno's Revenge*, depending on the story being told. Because of interactivity, and the fact that both stories are present, we decided to have an interactive title as well. Because of subtle differences between the detour events contextualizing the backbone events, each story being told has multiple versions, with different shades of meaning. The Backbone and Detour Micro-Core structure of the film is the one shown in Figure 10. There are three BBMC, six DTMC, and five Dynamic Objects used for navigating the film's structure. In Figure 10, lines between Micro-Cores indicate the different paths that can be followed, and the drawings indicate the objects that must be dragged into the Action Space from the Possible Action Space for that path to be taken.

The way the script was written provides further insight on how we arrived at this structure for the film. The first thing that was determined was the main chain of events that would compose the plot; first, a character (Fernando Moreno) would be seen practicing his shooting skills; second, Fernando Moreno would be looking for someone, and would receive indications on where to find that person; third, Fernando Moreno would follow the indications he received and shoot a man from a distance. These actions became the Backbone Micro-Cores of the film, and no matter what choices are made by the audience, they are always shown.

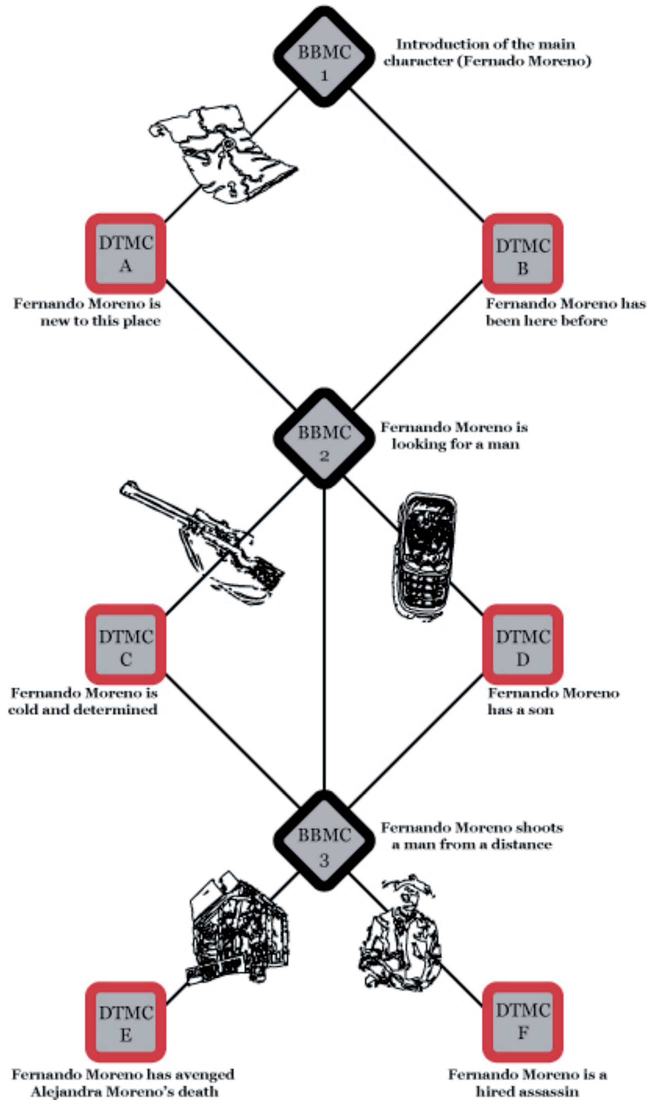


Fig. 10. Micro-Core structure of the film and dynamic objects.

Once the main sequence of events was determined, we began to think of different options that would link these events with one another. The idea was to connect them with detours that would allow users to co-construct different interpretations for the Backbone Micro-Cores. Coconstruction was used in two different, yet complimentary ways. One form of coconstruction occurs when audiences build Fernando Moreno's psychological profile and personality. By understanding his motivations for killing and the reasons why he is there, audiences are able to build the character from their own point of view. Every particular combination of Micro-Cores has its own profile, which viewers can read and interpret differently. During the first Interactive Moment (in BBMC 1), a map is available in the possible action space. When dragged into the action space, DTMC "A" is shown next, and viewers see Fernando Moreno asking a passing girl for directions. If the map is not dragged into the action space, DTMC "B" is shown next, Fernando Moreno is seen talking to a girl, and the dialogue between them reveals that they already knew each other. The purpose of this interaction is for viewers to coconstruct their own reading regarding Fernando Moreno's connection to the place where the action occurs. The second Interactive Moment (in BBMC 2) allows viewers to receive further information about Fernando Moreno. Audiences can choose between a shotgun and a cell phone. If the cell phone is dragged into the action space, DTMC "D" is shown, and Fernando Moreno is seen talking to his son over the phone while, if the shotgun is dragged into the action space, DTMC "C" is shown and Fernando Moreno is seen coldly practicing his shooting skills. Detours, in this case, enable audiences to coconstruct Fernando Moreno's state of mind right before the killing occurs. Additionally, as seen in Figure 10, the structure of the film allows users to include neither the shotgun nor the cell phone into the action space, in which case detours are skipped and the following BBMC is shown. This was done to experiment with a more flexible structure and to allow more open and ambiguous constructions of the film, that have more space for interpretation and coconstruction.

The second form of coconstruction occurs in the reading of the final Backbone Micro-Core. Fernando Moreno kills a man, and it is up to the viewer to interpret what has happened. The third Interactive Moment (in BBMC 3) determines two alternative endings. In one case, Fernando, after killing a man, visits the shrine of Alejandra Moreno and leaves the bullets as a sign that justice has been done (DTMC "E"). In the other case, he talks to his boss over the phone, and goes back to the place of the killing (DTMC "F"). Who is the man killed by Fernando Moreno? Has he killed the wrong man? Is he a hired assassin, or an avenger? Although the killing that takes place in BBMC 3 is the same, no matter what version of the movie is seen, the different contexts to the killing allow viewers to come up with their own answers to these questions and, through their coconstructive involvement, the final story is built by them, instead of being fully determined by the script.

7.3 Writing, Filming, and Programming

Once the film's structure was determined, over a series of brainstorming sessions that took place during a two-week period, the final script was written. Each scene was written independently, and then all possible combinations of the script were handed out to the team, to check for consistency and flow of the story. During this period, some minor modifications to the scenes were done. Filming took place during three days, after a two-week preproduction period. Each person in the acting and production crew had a printed version of the film's structure, and the detours were shot as alternative scenes. Every time a scene was shot, the script supervisor checked for continuity issues across all possible navigation paths. Afterwards, during a three-week period, each micro-core was edited as an independent chunk of film, using regular video editing software. By creating playlists with the independent chunks of film, each navigational path was seen as an independent film. Once all micro-cores were rendered as independent movie files, and each dynamic object was illustrated, the interactive version of the film was created, over a three-day period, using Flash. In the structure of the software, each micro-core is inserted into a different key-frame of the flash movie, using an FLVPlayback component. This allows us to separate the film's structure and playback software from the actual chunks of video that compose the film. This flexible structure easily enables the possibility to change the film's micro-cores, without having to change the source code (for example, the version with English subtitles uses the same software, but different videos than the version without them). The timing of the dynamic objects' fade-in and out, and the navigation between one micro-core and the next, is done by embedded cue points that act as metadata for each video chunk. Boolean conditions, according to the dynamic objects' final position within the frame, evaluate the audience's input. Overall, the software's structure is very simple and modular; therefore it is easy to create new films reusing the code written for each key-frame. Changing the navigational paths of the film is also very simple, because it only involves changing the Boolean conditions evaluated at the end of each video.

7.4 A First Encounter with Interactive Filmmaking: *Fernando Moreno's Crime or Revenge* in Front of an Audience

We invited 42 students from the Film Program at our University's School of Communications, to individually experience "Fernando Moreno's Crime or Revenge" at one of our computer labs, and then answer a survey that collected their opinion regarding the film, the system, and interactive filmmaking as a concept. The study was conducted with film students, and not general audiences, because in order for interactive films to exist in the future, we first need innovators and early adaptors who embrace the concept and create interactive audiovisual content that can later be distributed, and commercialized.

7.4.1 *The Study*. Each of the 42 students who saw the film at our lab took a survey divided into three sections. Each section had a particular objective.

(1) Section one was aimed at assessing coconstruction in the narrative of the film.
(2) Section two measured usability, and user experience of the interactive system.
(3) Section three collected the user's opinions about the future of interactive filmmaking.

7.4.2 *Assessing Coconstruction*. To measure the impact of co-construction, each participant was asked to watch the movie while the interactive options they took were registered. Then they were asked to answer the following open-ended questions: "Why has Fernando Moreno come to this town?" and "Who was the person killed by Fernando Moreno?"

What we were trying to determine was whether or not there is a correlation between the objects inserted into the film and the reasons that viewers believe motivated Fernando Moreno to kill a man. We chose to ask the reasons why he had come to town (instead of directly asking for the reasons of the killing), and use an open-ended question, so that the question itself would not condition or influence the answer.

Each answer to the first question was then, standardized according to four categories.

(a) Fernando Moreno has come to kill a man.
(b) Fernando Moreno has come to kill a man because he is seeking for revenge.
(c) Fernando Moreno has come to kill a man because he is a hired assassin.
(d) Other

Users who were classified into the "Fernando Moreno has come to kill a man" category did not specify the information we were looking for, and those who where classified into the "Other" category gave elaborate answers that had no reference to the killing itself. After the answers were standardized, they were classified according to the object the user had chosen during the third Interactive Moment (Table II).

Among the users that incorporated the "Shrine" during the third interactive moment of the film, 63.6% explicitly enunciated that Fernando Moreno had come to kill a man because he was looking for revenge, while none of them mentioned that he was a hired assassin. Among the users that incorporated the "Old Man" during the third Interactive Moment, 40% explicitly said that Fernando Moreno was a hired assassin, while 15% (3 users) said that he had come looking for revenge. Because of the fact that the third Interactive Moment determines the outcome of the story, it can be clearly seen that the majority of users who chose the Shrine saw Fernando Moreno as a man looking for revenge, while the majority of those who chose the Old Man saw Fernando Moreno as a hired assassin. No users identified Fernando Moreno as a hired assassin when they chose the Shrine, but three identified him as a

Table II. "Why Has Fernando Moreno Come to Town?"

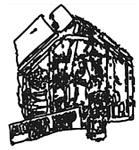
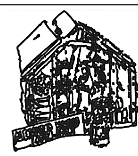
Third Interactive Moment	Kill a Man	Revenge	Hired Assassin	Other
 Shrine	6	14	0	2
 Old Man	8	3	8	1

Table III. Who is The Man Killed by Fernando Moreno?

Third Interactive Moment	Not the man he was looking for	Undetermined	The man he was looking for (Roberto Díaz)
 Shrine	0	2	20
 Old Man	17	2	1

man looking for revenge, despite having chosen the Old Man. To look for an explanation for this, we checked the other options these three particular users had taken during the first and second Interactive Moments, and found that all three of them had incorporated the "Map" during the first Interactive Moment. Because of this, during the first Detour they saw the conversation between the young girl and Fernando Moreno asking for directions. During that conversation Fernando says, "I'm here to collect some debts" which can be interpreted, in Spanish, as "I'm here to get even with someone." Those three users may have interpreted that scene differently because of that dialogue, or because they may have been influenced by the title of the film.

The second open-ended question, "Who is the man killed by Fernando Moreno?" provides information regarding the way coconstruction allows us to "rewrite" the meaning of certain events, and how viewers' interpretation can be influenced by the context provided to the backbone events of the plot. What we wanted to understand was how, according to the interactive preferences incorporated by the viewer, the scene where Fernando Moreno killed a man could be read in different ways. Answers were classified according to whether or not viewers had mentioned that Fernando had killed the wrong person, or if he had killed the man he was looking for (Roberto Díaz), and also according to the object chosen during the third Interactive Moment (Table III).

Table IV. Footage Requirements

Micro-Core Group	Duration	Percent of Total
Backbone	4:09	28,2%
Detour A	5:13	35,5%
Detour B	5:19	36,2%

Because 90% of the viewers who incorporated the "Shrine" considered that Fernando Moreno had killed the right man, while 85% of the viewers that incorporated the "Old Man" mentioned that he had not killed the man he was looking for, it can be clearly seen that, according to the context determined by the third Interactive Moment, the final Detour "rewrites" what audiences interpret in the scene of the killing.

In Table IV we show a brief analysis of the overhead in footage requirements introduced by interactivity compared with a lineal film. To do this we grouped the Detour Micro-Cores into two different sets (A and B). Set A considers the incorporation of the "Map" during the first Interactive Moment, the "Cell Phone" during the second Interactive Moment and the "Old Man" during the third one. Set B considers all other actions. If "Fernando Moreno's Crime or Revenge" was a lineal film, only one set of Detour Events would have been necessary, therefore, the other set can be considered additional requirements in footage because of interactivity. With an average run time of 9 minutes and 25 seconds, and a total of 14 minutes and 41 seconds of edited footage, our model required approximately 5 minutes of additional footage to make interactivity possible.

The final question in Section One of the study allowed participants in the experiment to leave comments and feedback regarding the film. Three users commented that they were frustrated when, despite not having chosen the "Shotgun" during the second Interactive Moment, it appeared anyway during the killing. This is a problem that was not foreseen during the writing of the script. The detour after the second Interactive Moment uses the shotgun as a form of configuring Fernando Moreno's character, by showing him as a cold blooded criminal instead of what happens in the alternative detour, where he is shown as a father calling his son. We did not realize that the shotgun would appear anyway at the following backbone event. A solution for this is to eliminate the "Shotgun" as an option during the second Interactive Moment, leaving only the "Cell Phone" as a dynamic object, and using the other scene as a default path when the "Cell Phone" is not dragged into the action space. A new version of the film with this structure is available online at http://cineinteractivo.ing.puc.cl/newversion.

7.4.3 *User Experience and Usability.* Section 2 of the study evaluated the system's interface and assessed the overall user experience. Users' level of agreement or disagreement to 20 different statements was measured using a five-level Likert scale. Table IV shows the summary of the results.

All items measuring the system's usability reflect that the vast majority of users evaluate it positively, and consider the system as simple (items 1 and 18), intuitive (item 7), easy to use (item 11 and 12), easy to remember (item 13 and 14), and responsive (item 19). Items regarding errors and exceptions show that most users did not experience any major difficulties (items 5, 15 and 16) although in those same items it is possible to identify a single user who evaluated the system poorly due to a computer crash. Finally, regarding the overall experience, a remarkably high percentage of users evaluate the experience as fun and agree that they felt comfortable interacting with the system (items 4 and 17).

7.4.4 *Evaluating Interactive Cinema.* Because the participants in the study were all film students, we were interested in their opinion regarding Interactive Cinema in general, and not just this particular short film. Section 3 of the study evaluated participant's opinion regarding the broader idea of Interactive Cinema, and the model we have developed. Users' level of agreement or disagreement to 7 different statements was measured using a five-level Likert scale. Table V shows the summary of the results.

Table V. Usability and User Experience

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	Icons that represent the objects are clear and simple to understand.	64,3%	33,3%	0%	2,4%	0%
2	The objects inserted into the film had an effect over the plot.	36,6%	48,8%	9,8%	4,8%	0%
3	I wish there were more moments to incorporate objects into the film.	59,5%	28,6%	9,5%	2,4%	0%
4	I felt comfortable interacting with the system.	47,6%	33,3%	14,3%	0%	4,8%
5	I had problems incorporating objects into the film, or interacting with the system	2,4%	4,8%	7,1%	14,3%	71,4%
6	The elements/objects I added to the movie had an important role in the unfolding of the action.	11,9%	47,7%	19%	19%	2,4%
7	The system is intuitive and easy to use.	66,7%	26,2%	4,8%	2,3%	0%
8	Because of interactivity and having to use the system, I sometimes got distracted and stopped paying attention to the unfolding of the story.	0%	14,2%	26,2%	28,6%	31%
9	Initial instructions were sufficient to understand how to use the system.	73,8%	21,4%	2,4%	2,4%	0%
10	I never understood what the objective of interacting with the system was.	0%	2,4%	14,3%	28,6%	54,7%
11	It was easy to know what to do when I had the option to interact with the system.	54,8%	35,7%	7,1%	2,4%	0%
12	I had to learn many things to use the system.	0%	2,4%	0%	21,4%	76,2%
13	Once I learned how to use the system, I had no problems interacting with it.	85,7%	14,3%	0%	0%	0%
14	If I saw an Interactive Film a month from today, I would remember how to use the system.	83,3%	14,3%	0%	2,4%	0%
15	There were situations in which I tried to perform an action, but wasn't able to.	2,4%	11,9%	9,5%	26,2%	50%
16	I had to stop watching the movie because of errors in the system.	2,4%	0%	4,8%	19%	73,8%
17	The Interactive Film was fun to watch.	47,6%	38,1%	14,3%	0%	0%
18	The system is simple.	81%	19%	0%	0%	0%
19	The system is quick and responsive.	71,4%	26,2%	0%	2,4%	0%
20	I think that the system lacks some features.	5,5%	16,7%	16,7%	25%	36,1%

Statements included in the study evaluated general opinion regarding Interactive Cinema (Items 4 and 5), as well as personal preferences (Items 1, 6, and 7). Results show a very high level of approval regarding Interactive Cinema's future as a viable form of entertainment, and slightly lower ratings when it comes to personal preferences. This shows that the majority of future filmmakers who participated in the study recognize the value of Interactive Cinema, even if they don't prefer it themselves. Finally, items 2 and 3 show the openness and eagerness of future filmmakers to experiment with new ways of distribution of audiovisual content, like the Internet and mobile devices.

8. CONCLUSIONS

This article reflects our approach towards Interactive Filmmaking, and shows that this vast and innovative media can provide us with creative and unique tools for exploring the hidden narrative worlds behind a "what would have happened if...". Interactive films, despite the new challenges and problems they propose, have the potential to become a powerful and refreshing reinvention of a media born through technological innovation, which has always been open to change. In Mark Cousins's [2004]

Table VI. Evaluating Interactive Cinema

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
1	I would like to see more Interactive Films in the future.	55,3%	36,8%	7,9%	0%	0%
2	I would like to see Interactive Films on my cell phone or other mobile devices.	26,3%	23,7%	39,4%	5,3%	5,3%
3	I would like to see Interactive Films on the Internet	57,9%	31,6%	7,9%	0%	2,6%
4	I believe that Interactive Cinema has a future in the industry of entertainment	42,1%	52,7%	2,6%	0%	2,6%
5	I believe that interactive experiences are the future of communications and entertainment.	36,8%	36,8%	18,5%	7,9%	0%
6	Experiences like Interactive Cinema are the type of entertainment I would like to enjoy in the future.	35,9%	38,5%	12,7%	10,3%	2,6%
7	I would like to see an Interactive Feature Film.	63,2%	26,3%	5,3%	2,6%	2,6%

words, ‘It is helpful to imagine cinema evolving as a language or replicating like genes because doing so illustrates that film has a grammar and that in some ways it grows and mutates’.

Fernando Moreno’s Crime or Revenge is a first approach towards Interactive Filmmaking using detour narrative and coconstruction. In the study we conducted with film students, both variables that were indirectly measured—if Fernando Moreno killed the right man or not and if he is a hired assassin or an avenger—show that our model for interactive filmmaking allows writers to use audience interpretation as a tool for building audiovisual experiences that narrate two (or more) different stories. Viewer reception and interpretation of a film is not new. Coconstruction, which is the intentional use of this reception and interpretation as a narrative tool within an interactive environment, is.

We believe that the detour narrative model along with coconstruction can be an extremely powerful tool for creating steerable narrative experiences, and that its full potential is yet to be discovered. Further empirical investigation must be done regarding coconstruction and its narrative uses. The following questions remain unanswered and require future narrative experiments, with both audiences and authors, to shed light on them.

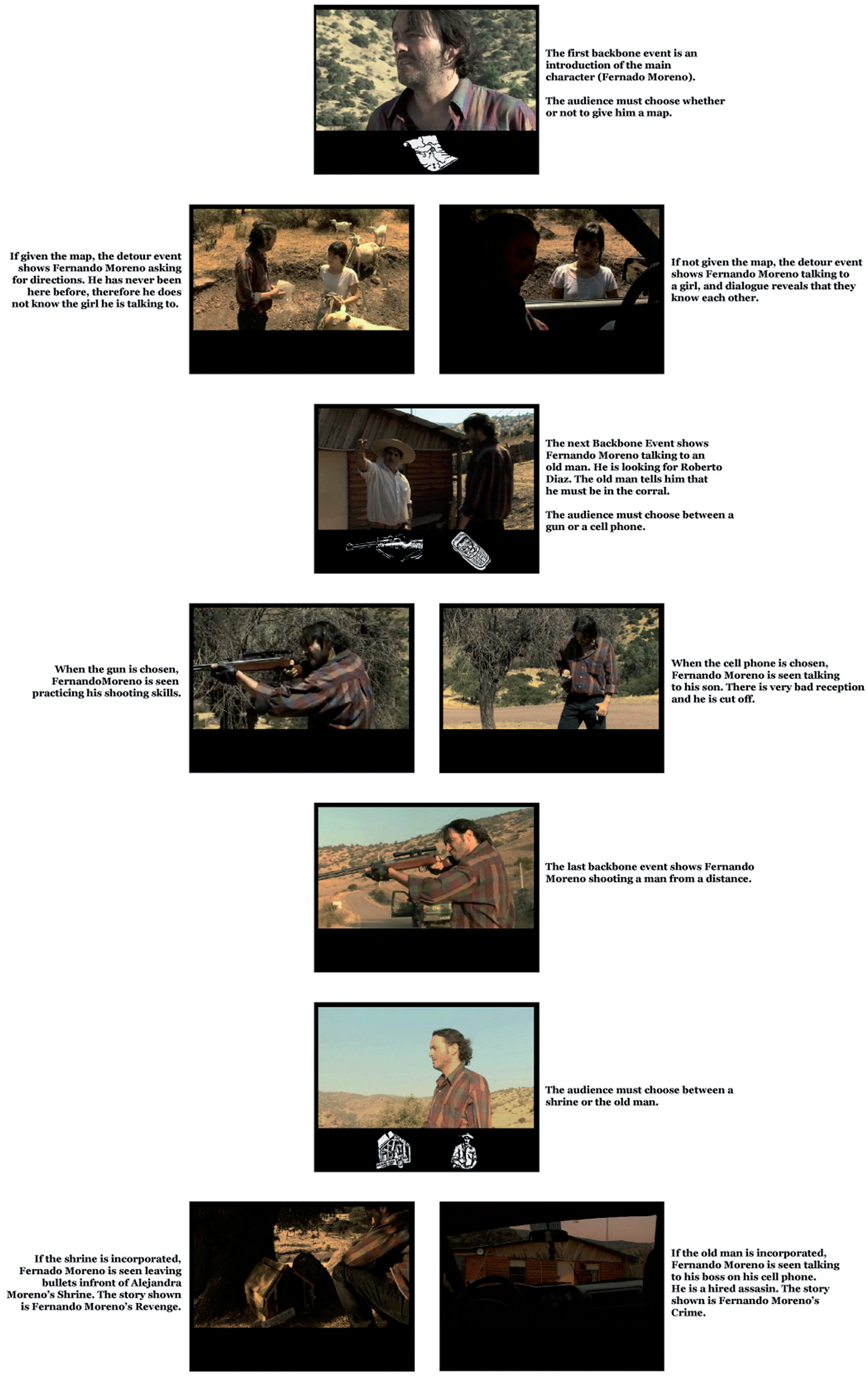
(1) How does the use of coconstruction alter they way we design, write and film audiovisual experiences?
(2) How can authors easily include coconstruction into their scripts?
(3) How does the audience’s cultural background influence coconstruction? Is this predictable?

Additionally, it is possible to detect computational requirements within our work that would make the creation of these audiovisual experiences much easier. Examples of this are the following.

(1) Software based on the coconstructive detour narrative model that allows the production of Interactive Films without the need of programming, following similar graphic structures as the ones used to produce detail-on-demand video by the Hyper-Hitchcock editor [Shipman et al. 2008].
(2) Nonlinear video editing software that allows easy management of each microcore as a separate chunk of video.
(3) Production management software and script writing software for nonlinear and branching scripts.

The applications that this narrative model might have in multiple fields like education, interactive television, e-learning, marketing, art, performance, and others must be explored, and further research must be done. We hope that this article serves as a precedent for future work in diverse fields and disciplines, because it is only through interdisciplinary efforts that we will gain further understanding and insight of the challenges and opportunities that new media provides us with.

APPENDIX


The first backbone event is an introduction of the main character (Fernado Moreno).
The audience must choose whether or not to give him a map.
If given the map, the detour event shows Fernando Moreno asking for directions. He has never been here before, therefore he does not know the girl he is talking to.
If not given the map, the detour event shows Fernando Moreno talking to a girl, and dialogue reveals that they know each other.
The next Backbone Event shows Fernando Moreno talking to an old man. He is looking for Roberto Diaz. The old man tells him that he must be in the corral.
The audience must choose between a gun or a cell phone.
When the gun is chosen, FernandoMoreno is seen practicing his shooting skills.
When the cell phone is chosen, Fernando Moreno is seen talking to his son. There is very bad reception and he is cut off.
The last backbone event shows Fernando Moreno shooting a man from a distance.
The audience must choose between a shrine or the old man.
If the shrine is incorporated, Fernado Moreno is seen leaving bullets infront of Alejandra Moreno's Shrine. The story shown is Fernando Moreno's Revenge.
If the old man is incorporated, Fernando Moreno is seen talking to his boss on his cell phone. He is a hired assasin. The story shown is Fernando Moreno's Crime.

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APPENDIX D

PAPER IV

Digital access to interpretation information at the Royal Botanic Gardens, Kew: the "smartphone wall"

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Digital access to interpretation information at the Royal Botanic Gardens, Kew: the “smartphone wall”

Renato Verdugo, Angela McFarlane & Miguel Nussbaum

Abstract

Museums struggle to find ways to deliver personalized experiences to their visitors as each audience member has different expectations and objectives. The increasing number of visitors carrying with them smartphones or internet capable devices offers the possibility to use this hardware to manage the balance between presence and absence of interpretation information according to each visitors’ needs. This article presents an evaluation of visitor engagement and perceived quality of the experience when visitors’ smartphones are used to access content at the Royal Botanic Gardens, Kew in London, UK. Results show that there is an appetite for rich content when it is immediately present in the physical interpretation but if extended content is accessed via a digital device this reduces visitors’ engagement and does not necessarily improve visitors’ perceived quality of the experience. Integrating visitors’ smartphones into interpretation strategies appears to risk hitting a “smartphone wall”. As technology evolves and more research is conducted practitioners will gain further insight into what this “smartphone wall” looks like and how to avoid it.

Keywords: Mobile technologies, Smartphones, Informal Learning, Botanic Gardens, Interpretation.

1. Introduction

Museums enable visitors to encounter directly objects of cultural, aesthetic, historical, natural, or other value. Yet solely encountering an object or the mere existence of a physical space that holds a collection is not enough to guarantee that visitors will undergo a learning experience (Eisner, 2009; Dierking and Falk, 1992); because of this, alongside the curatorship of their collections, museums must also design the visitors’ experience so as to facilitate a better understanding and appropriation of the objects being presented. Prioritizing investment in areas where the greatest impact can be achieved becomes a major challenge for organizations with finite resources and budgets. To communicate effectively with their audience and provide appropriate contextual information on their exhibits, museums must understand how different on-site strategies to deliver and access content affect visitor engagement. This article presents an empirical assessment of the effect of offering access to rich content via visitors’ smartphones for on-site delivery of interpretation information at the Royal Botanic Gardens, Kew in London, UK.

1.1 Kew as a museum

For the purpose of this study the Royal Botanic Gardens, Kew has been compared to a museum; this is not an arbitrary decision. Beyond its natural beauty and aesthetic appeal to visitors, the Gardens present a living collection that has been arranged according to taxonomic and geographic relationships -i.e. the Gardens are a curated, living exhibition. There are of course differences between the Gardens and a conventional museum, however we propose that much visitor behavior, particularly in relation to access to interpretation content, is comparable.

Since its opening in 1759, selection and arrangement of the collections at Kew has always had a scientific and economic purpose. Today Kew is a world leading plant science, sustainability and conservation organization that conducts worldwide projects with more than 800 organizations in more than 100 countries. Therefore, its double role as a scientific organization and one of London’s major visitor attractions affords an opportunity to establish a dialog with visitors around the importance of plants, conservation and biodiversity.

This favorable context does not, on its own, establish the necessary conditions for audiences to engage with the collections for the purpose of learning. As with any museum, the Gardens offer an informal learning scenario – in contrast to formal learning environments like schools and universities. The challenge is how to deliver information to visitors that are not following a unique path of exploration; do not have equivalent backgrounds or previous knowledge; and have diverse motivations to visit. Therefore, learning as an outcome of a visit depends on the articulation of an engaging scaffolding that, while enabling visitors to appropriate information from or about the exhibit, fits within their a-priori personal agenda, background and motivation to visit. As noted by Kuflik et al. (2011) "visitor's experience in museums tends to be personal, self-motivated, self-paced, and exploratory" and therefore, when shaping the visitor experience, museums must consider their visitors' particular motivations and expectations; what brought them to visit and what they expect to get from the experience. Each museum, according to the nature of its collections and value proposition to its visitors, attracts a particular audience with a specific mix of expectations and objectives. Falk et al. (1998) propose six non-exclusive categories of motivation for visiting that inform a visitor's agenda:

- Place: relating to the fact that a place has particular emblematic value (leisure, recreational, cultural, etc.) to the region where it is located.
- Education: relating to the aesthetic, informational or cultural content of the museum.
- Life cycle: relating to the particular moment in life that visitors are going through (e.g.: childhood).
- Social event: related to the idea that the visit is a special social activity for families, friends or acquaintances that decide to have a "day out" together.
- Entertainment: related to the leisure value of the museum.
- Practical Issues: relating to external factors that determine a person's visit to a museum like weather, entrance fee, location, etc.

The Royal Botanic Gardens, Kew conduct a yearly exit survey with 900 interviews split evenly between summer (April to September) and winter (October to March). This data sketches a broad visitor profile and queries the reasons that motivate people to visit (Appendix A); all categories of motivation proposed by Falk et al. are present, but they are not equally represented. Most visitors are driven by either an interest in the place or gardens in general or because of Kew's entertainment and leisure value. Other categories -like life cycle, education and practical issues- are only present in small groups of the visitor population. A very small fraction of visitors explicitly enunciate education, learning or professional interest as a drive to visit. This presents a challenge when designing interpretation strategies around the Gardens because most people are not actively seeking learning opportunities. Excessive signage and invitations to engage might have a potentially disruptive effect on visitors' experience and appreciation of the aesthetic and recreational value of the Gardens. Despite these issues, data from the same yearly study shows that a majority of the public consider -upon exiting- that their visit to Kew has had learning and/or educational value (Appendix B). This means that despite not being a driving force to visit, once people are on-site they discover -and value- Kew’s learning opportunities. Consequently, the dialogue between the Gardens’ public and the scientific and conservation efforts at Kew depends on a delicate balance between presence and absence; visitors must be given the opportunity to engage with additional information that contextualises the collections, while at the same time be given space and time to experience the aesthetic and recreational value of one of London’s most scenic attractions.

1.2 Interpretation at Kew

Current interpretation at the Royal Botanic Gardens, Kew uses three main components; static panels, video and online content. Throughout the Gardens panels with interpretation information are placed next to specific plants, collections or historic features; these panels provide visitors with general information, e.g. referring to the overall collection presented in that part of the garden or plants of particular botanic, economic or other interest. Additionally, two types of material that provide in-depth information regarding the collections have been created – video and web-based species pages. Species pages combine scientific, geographic, historical, economic, environmental and other types of information to give visitors an in-depth review of specific plants, their origins, uses and current conservation status. Videos linked to interpretation are all under 5 minutes long and cover a range of topics, e.g. how the species at Kew relate to their natural environment and how the plants grow in the wild. In general, panels provide a few key ideas regarding the species and are basic enough to be of interest to broad audience segments; videos and particularly species pages cater to those who are looking for more information.

To balance the trade-off between detailed information availability and on-site information overload, a combination of analogue and digital access to interpretation content is used at Kew. Informed by in-depth visitor behaviour research (Waterson & Sanders, 2012) Kew commissioned its first mobile app in 2011(available for iOS and Android devices); the app considers four core functionalities: wayfinding (location aware map), seasonal highlights, general information and “*dig deeper*”. The first three were designed specifically to respond to observed and reported visitor needs and help visitors plan their overall visit, find their way around the site and choose activities, attractions and places to see. The "*dig deeper*" section is more experimental. It allows any visitor to access on demand video and species pages by scanning QR codes (a type of matrix barcode, abbreviated from Quick Response Code) with a built-in reader within the app that uses the phone's integrated camera. The app retrieves content from Kew's website and optimizes it to the phone's screen size, which contributes to mitigate certain usability issues related to smartphones' small screen size (Sanchez & Branaghan, 2011). These codes are also readable using a third party scanner app, in which case content is accessed through a web browser. QR codes digitize the hyperlink to the related content without the need for the user to manually type a URL. This solution leaves the panels as physical objects around the gardens and incorporates QR codes as ways of accessing more detailed information about the plants in the collections. The codes are incorporated in either the interpretation panels or a selection of the labels used for collections management at Kew.

Today's visitors demand and expect personalized experiences that fit their specific needs on the day of their visit (Ruiz et al., 2011).This can be offered by combining digital and analogue access to content as part of an interpretation strategy that allows for a balance between presence and absence of contextual information around the Gardens. Static video capable panels are expensive and intrusive and so cannot be used in the same quantity as panels carrying access codes to rich content. Yet relying on the visitors' smartphones raises a series of questions regarding visitor experience and the use of mobile devices. As the range of technologies and tools to deliver information to visitors gets more complex and rich, it becomes necessary to assess how these new methods impact visitor engagement. A digital interpretation strategy offers an alternative way of delivering content to visitors, increasing their agency and control over self-regulated learning (Sha et al., 2012); it broadens the range of possibilities available to communicate with museum audiences but it also carries limitations and obstacles. Digital technology must be understood as a means to an end, not an end in itself. Literature regarding smartphone use in museum contexts focuses on either showcasing new developments and applications, eg Bihler et al. (2011), or on the technology behind said developments, eg Bruns et al. (2006). Despite the fact that the way technology is used is the key to its effectiveness (Hokanson & Hoper, 2000), there is a lack of comparative studies that ask how the new possibilities provided by mobile technologies compare to the alternatives that don't use them. Sung et al. conducted a study that compared the use of an interactive multimedia guide with an equivalent print workbook (2010). Because their study was aimed at college students within a specific university course instead of general audiences it does not shed light on the issues raised in this article, however, it does constitute a methodological precedent; establishing technology as an independent variable allows for understanding how its inclusion changes visitors' experience. Gaining insight on how different ways of delivering information actually changes the visitors' experience at museums enables a better understanding of the impact of innovative interpretation strategies. With this goal in mind, the main research question of this study is:

[RQ] How does the reliance on visitors' smartphones for on-site access to interpretation information change visitor experience and engagement at the Royal Botanic Gardens, Kew?

This article presents three experimental treatments that compare audience engagement and perceived quality of the experience through 'present' ie immediate versus 'absent' ie remote, access to interpretation content.

2. Method

To assess the differences between immediate and remote access to interpretation information visitors were offered exactly the same content via different presentation and retrieval methods. A specific plant housed in the desert zone of the Princess of Wales Conservatory at Kew was chosen, the saguaro cactus (*Carnegiea gigantea*). For this particular plant three different interpretation panels were designed (Figure 1); all of them were based on the standard interpretation layout and design used at Kew. Each had the same 120-word text that gives general information about the cactus. Alongside the text, visitors could watch a 3-minute video and read a 1200-word document containing the saguaro's species page. It was through the method of access and retrieval of the video and species page that panels differed from each other; in one case, the video and species page was available through a screen and a print document within the panel, while for the other two panels both resources were available online through either QR Codes or short-URLs (Table 1). QR Codes offer a quick way of requesting content but not all users are familiar with them and they do have known usability issues (Shin et al, 2012); on the other hand, URLs are a more established way of accessing content and may be more recognizable to the visitor although the effort required to use them is greater. Because of these

differences two separate treatments based on visitors’ smartphones were designed.

Treatment	**Technology**	**Description**
Treatment 1 (*Paper & Screen)*	7-inch screen Print document	The screen was used to loop the video. The species page could be found in a pocket within the panel.
Treatment 2 (*QR Codes*)	QR Codes	The panel contained QR Codes that linked to online versions of the video and the species page. Visitors could scan them using either the Official Kew Gardens App or a third-party QR code scanner.
Treatment 3 (*URLs*)	Short-URLs	The same as in Treatment 2 except that the QR Codes were replaced with Short-URLs that visitors could access through the web browser of their mobile phones or capture for future reference.

Table 1: Description of each experimental treatment.

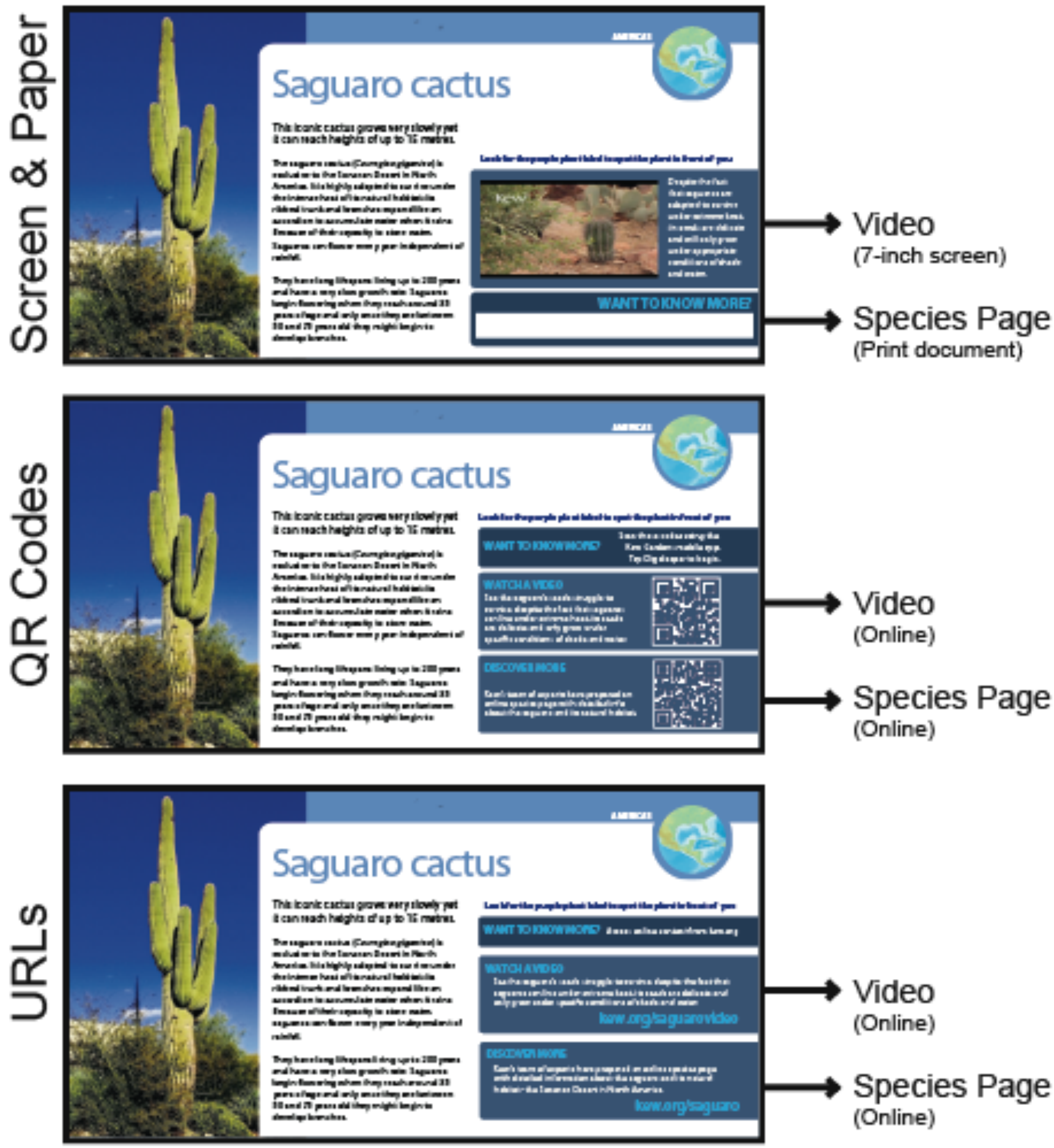

Figure 1: Panels designed for the study offering different ways to access the video and species page.

The study was conducted over a three-week period during which 300 groups of visitors (100 for each treatment) participated in the experiment. On any given day three time slots were established and each panel was displayed next to the saguaro cactus for a period of time. The researcher invited visitors to participate in an experiment regarding prototypes of possible new designs for interpretation panels. Individuals who were visiting as a part of a group were asked to participate together with the other members of their party, because this is the way they would normally encounter interpretation panels during their visit. Those who agreed to participate were presented with one of the three panels and were asked to take a look at it for whatever period of time they felt suitable; they were explicitly asked to do what they would normally do when they encounter interpretation information around the Gardens and to not feel any pressure to read the whole text, watch the whole video or access online content if they would not normally do so. When an Internet connection was required to access digital resources through the visitors' smartphones (*QR Codes* or *URLs*), this could be done through the visitors' own 3G-network connectivity or Kew's free wireless network.

The experimental design was aimed at capturing four visitor responses: engagement, experience, alignment with target audience, and smartphone availability (Table 2). A three-question survey (Figure 2) covered with a sheet of paper was given to visitors when they were presented with the panel; they were told to uncover it whenever they felt they had finished looking at the panel. The survey asked visitors to register the amount of content they had read/viewed of each part of the panel (text, video and species page) using the scale *all*, *some* or *none*. It also asked visitors to indicate which of the following descriptors applied to the information presented to them in the panel: *interesting*, *too basic, too detailed, entertaining* and *not for me/us*. Finally, it asked visitors to indicate what they would tell other visitors regarding the panel –ie likelihood to recommend- using a 1 to 5 star rating scale; *(1*) Didn't Like It, (2*) Don't Bother, (3*) Just Fine, (4*) Really Good, (5*) The Best.*

Additional to the questions in the survey, the researcher timed how long visitors looked at the panel by starting a stopwatch once visitors were left alone in front of the panel and by stopping it when visitors removed the sheet that covered the survey. As visitors returned their answers, the researcher asked them if they had smartphones or internet capable handheld devices with them. Table 2 links each source of empirical data with the appropriate item being assessed in the study.

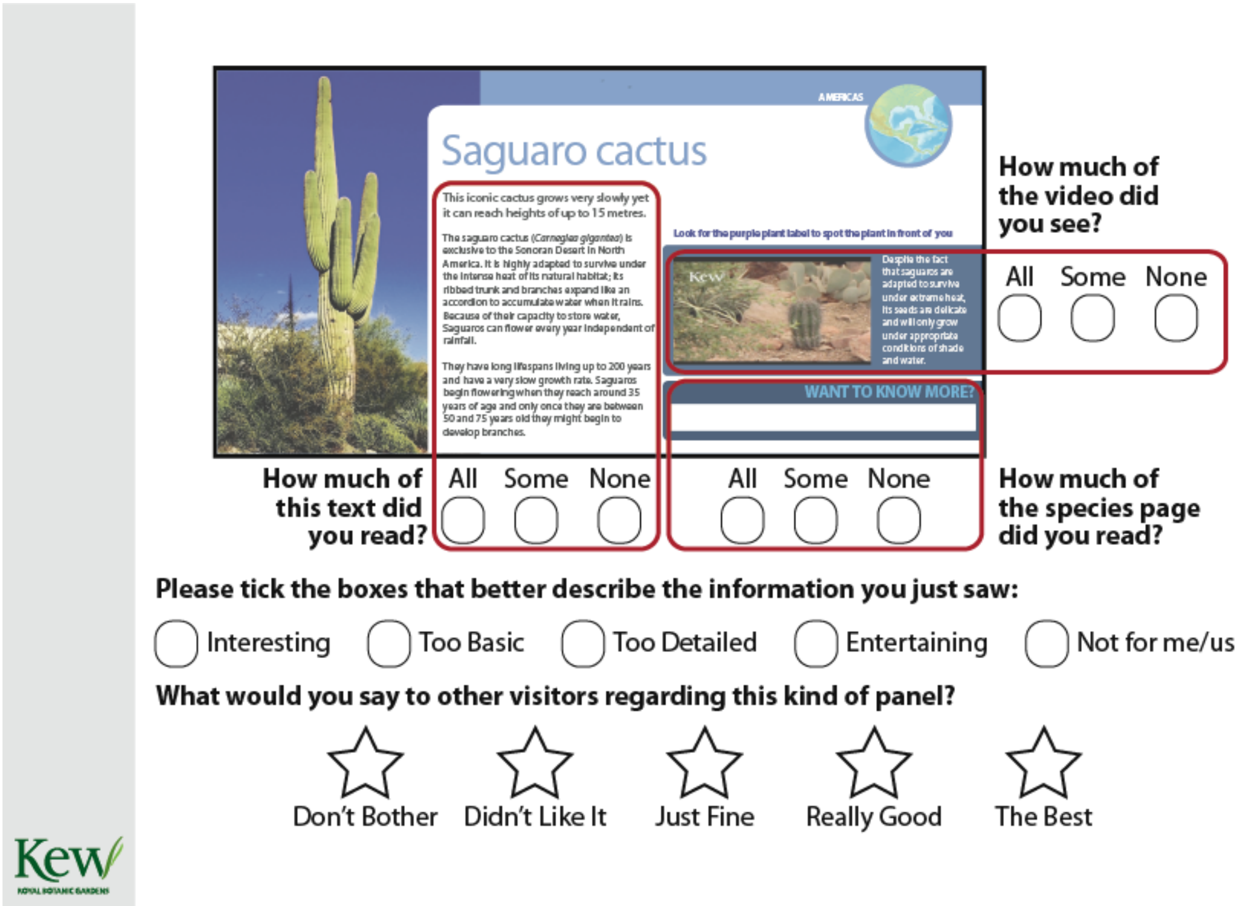

Figure 2: Example of survey given to visitors who participated in the study. It uses an image of the panel visitors have in front of them to reference each section and assess the level of consumption of text, video and species page and responses to the experience as a whole.

Item	Definition	Form of empirical assessment
Engagement	Level of involvement that visitors show when they encounter interpretation information.	Time spent looking at the panel and the level of consumption of each part of the panel (text, video and species page).
Perceived quality of visitor experience	Evaluation that visitors do of their encounter with interpretation information.	Star rating given to the panel.
Alignment with target audience	The extent to which the panel and content used are appropriately designed to be appealing and engaging to Kew’s visitors.	Descriptors assigned to the information seen in the panel.
Smartphone availability	Fraction of Kew’s visitors that have smartphones or Internet capable handhelds available to them during their visit.	Direct question asked to visitors.

Table 2: Items being evaluated by the study and their form of empirical assessment.

3. Results and Analysis

Experience and engagement

The two main data points of the study, which answer the research question proposed in the introduction, were the assessment of the visitors’ experience and engagement when they encounter panels with interpretation information at the Royal Botanic Gardens, Kew. Table 3 presents the results for the star rating given to each panel and the amount of time spent looking at them by visitors. Table 4 presents the level of consumption for each part of the panel.

	N (Groups of visitors)	TIME m:ss		STAR RATING out of a total of 5	
		Mean	**Std. Deviation**	**Mean**	**Std. Deviation**
Screen & Paper	100	1:42	1:00	3.65	.63
QR Codes	100	0:49	0:39	3.51	.72
URLs	100	0:40	0:22	3.52	.56

Table 3: Time (engagement) and Star Rating (experience) evaluation

A one-way between subjects ANOVA was conducted to test for differences between the time groups of visitors spent looking at a panel when presented with the Screen & Paper, QR Code or URL treatments. Results show that time spent looking at a panel varies significantly depending on the panel being shown, $F(2, 297) = 60.118$, $\eta^2 = .28$, $p < .001$. Post-hoc Games-Howell comparisons showed that the *Screen & Paper* panel had significantly higher viewing times than the other two panels at the .01 level of significance; the comparison between the time spent looking at the *QR Code* and *URL* panels was not significant.

ANOVA of the star rating ie approval rating given to each panel yielded no significant differences between samples, $F(2, 297) = 1.501$, $\eta^2 = .01$, ns.

	N (Groups of visitors)	TEXT			VIDEO			SPECIES PAGE		
		All	**Some**	**None**	**All**	**Some**	**None**	**All**	**Some**	**None**
Screen & Paper	100	51%	46%	3%	33%	64%	3%	11%	53%	36%
QR Codes	100	80%	20%	0%	1%	2%	97%	0%	0%	100%
URLs	100	78%	22%	0%	0%	0%	100%	1%	0%	99%

Table 4: Content consumption level for each part of the panel (text, video and species page).

The experience and engagement results show that when the method of retrieval requires the use of the visitors’ smartphone, engagement as measured by the % content accessed drops considerably yet the visitors’ perceived quality (star rating) of the experience remains constant. The *Screen & Paper* panel has a considerably higher observation time –more than twice as long as the *QR Code* and *URL* panels. This is explained by the fact that an overwhelming majority of visitors look at the video (97%) or read the species page (64%) when it is immediately available and isn’t hidden behind a “smartphone wall”. Table 4 shows that the accessing of content through smartphones –either through a QR Code or URL- is very low; only three groups of visitors scanned the code and only one accessed content through the short URL. The star rating scale used to measure visitor experience shows that immediate availability of the video or the species page – despite reaching a broader audience – does not change the visitors’ perceived quality of the experience when encountering the panel.

Alignment with target audience

Asking visitors to assign descriptors to the information shown in the panels was designed to evaluate the extent to which the panels and content used at Kew are appropriately pitched for visitors –do they find them appealing? Table 5 shows the results for each descriptor by treatment.

	N (Groups of visitors)	**Interesting**	**Entertaining**	**Too Basic**	**Too Detailed**	**Not For Me/Us**
Screen & Paper	100	82%	26%	0%	9%	2%
QR Codes	100	93%	3%	1%	6%	1%
URLs	100	96%	7%	1%	3%	0%

Table 5: Descriptors assigned to the information available through each panel type.

A vast majority of visitors consider that the information available through the panels is interesting. When video is immediately available, 1 out of 4 groups also identify the panel as entertaining which is not the case when video must be accessed through the visitor’s smartphone. Very few groups of visitors consider the panels to be either too detailed or too basic, even when the 1200 word printed species page is available, showing that overall the quantity and level of information available to visitors is appropriate. Finally, the fact that only 3 out of 300 groups who participated in the experiment consider the panels as “not for them” shows that visitors recognize panels as something intended for them in particular –not for other groups/types of visitors.

Smartphone availability

To understand the implications of the different reactions to the three panels presented, it is important to know how many of Kew’s visitors have a smartphone or an internet capable handheld device available to them during their visit. Table 6 shows the number of groups in which one or more visitors had a smartphone or internet capable device with them.

	N (Groups of visitors)	**Smartphone Availability**
Screen & Paper	100	56%
QR Codes	100	62%
URLs	100	58%
All Groups	300	59%

Table 6: Smartphone availability.

All three samples show a fairly consistent number; around 60%, of Kew’s visitors either have a smartphone with them or are visiting with someone who has one. This data becomes relevant when considering the drop in engagement levels shown when the *QR Code* and *URL* panels are compared to the *Screen & Paper* panel. Because the use of QR codes and URLs require visitors to have their own smartphones it is expected that engagement might drop because inevitably, given the market penetration of such devices, not all groups of visitors will have the necessary hardware with them, however the data show that even when a group has such a device they are extremely unlikely to use it to access the rich content offered.

4. Discussion

The *Screen & Paper* treatment shows that visitors are interested in consuming content beyond the basic information provided by the panel text –most watch at least some of the video and/or read parts of the species page, and this doubles the average time spent looking at the panel when compared to those who only read the panel text. The study shows that despite the high availability of smartphones, there is very low use of them; although the specific causes of this were not explored in this study it seems that any of the following may be factors:

- Visitors’ motivation to access additional information is weak, and therefore content consumption drops when it encounters a barrier to access information – this may be a general lack of motivation or related to this particular instance ie the Saguaro cactus.
- When content must be accessed through a smartphone, visitors cannot assess the value of the additional content directly and must rely on descriptions, which may reduce their interest in it.
- Visitors may not know how to use the advanced functionalities of their smartphones, or do not use them habitually.
- Visitors do not want to use their smartphones during their visit which may be a function of the nature of a visit to a botanic garden or due to some other factor eg the perceived cost.

The first scenario relates to the visitors’ agenda and motivation to visit. As explained in the introduction to this paper, a desire to learn does not drive the decision to visit Kew rather it is a positive by-product of a visit. This factor might also explain the lack of differentiation that the visitor experience evaluation shows irrespective of the design of panel presented to the group and the engagement level achieved through it; because visitors were not seeking a learning opportunity, they tend to give the same rating to the panels independent of the content they actually access through it.

The other scenarios are specific to the use of smartphones. It is possible that despite their very broad market penetration, smartphones still present a learning curve that excludes some users from the benefits they afford. Having a very powerful digital tool in your pocket does not necessarily imply knowing how to harness it. Thus visitors may have no models of the type of content they can access via their phone, or the costs of doing so. Demonstrating to visitors how to use their devices and the rich variety of content they can access as a result might broaden the user base of high-end smartphone features.

The final scenario describes an even more challenging situation as it suggests that users see smartphone use as incompatible with a visit to a botanic garden. The idea that equates smartphones with being “wired in” or working might affect visitors’ willingness to use their devices during an experience which is primarily about connecting with the natural world (Appendix A).

5. Conclusions

Using visitors’ smartphones to provide additional interpretation information to visitors at museums and other educationally oriented attractions provides a series of potential benefits when designing an interpretation strategy. However, widespread ownership and increasing daily use does not mean that that smartphone use is inevitable or comes without any tradeoffs. The experience at the Royal Botanic Gardens, Kew in London, UK of offering digital access to interpretation information shows that smartphone usage is far from being a generalized practice among its visitors. Despite the fact that a majority of visitors have access to smartphones or internet capable handheld devices, it seems a very small fraction of visitor groups use them as a vehicle to access additional information about Kew’s collections and displays. Smartphones’ high usage in daily activities has not yet been mirrored in educational and learning scenarios (Shin et al, 2011). Integrating visitors’ smartphones into interpretation strategies appears to risk hitting a “smartphone wall”. There is an appetite for rich content when it is immediately present in the physical interpretation but if the extended content is accessed via a digital device this reduces visitors’ engagement and does not necessarily improve visitors’ perceived quality of the experience. This may be caused by a combination of factors: visitors’ specific agendas and motivations to visit, a lack of interest in the instance used in this study, a lack of familiarity and therefore the value of the extended content, the difficulties of harnessing the high-end functionalities of smartphones and visitors’ reluctance to use smartphones during their visit.

Independent of which reason is dominant –as this might be dynamic and change overtime- this study shows that digital interpretation strategies must find ways to overcome the "smartphone wall". Future work must be conducted across various museums and informal learning scenarios to evaluate the forms this phenomenon takes in contexts other than the saguaro cactus and in settings other than the Royal Botanic Gardens, Kew. Additionally, audience segmentation should be considered to understand how different visitor profiles react to the "smartphone wall"; is it transversally present or does it vary according to each museum's specific mix of visitors' agendas, expectations and backgrounds?

These findings inevitably cause us to reconsider the decision to use this particular approach to offering interpretation content in the Gardens and whether the investment in this element of the programme was worthwhile. The major expense involved in providing interpretation information to visitors is producing content. Kew's species page project has been going on for over two years. During that period, more than 400 pages have been created and new ones are added weekly. Each page is the result of the coordinated efforts of botanical experts from Kew and around the world who must work alongside designers, photographers, editors and web developers. Species pages take a minimum of six weeks to produce from their initial research stages to their online distribution. They are one of the most popular elements of the main Kew website. Similarly video production has a cost; footage of plants growing in the wild must be licensed from third-party sources and on-site shooting requires complex logistics and planning. Having invested in producing high quality content, Kew is experimenting with the best ways to make that content accessible to the intended audiences. Currently this is via more traditional web based routes including third party and video sharing sites. Visitor research and this study show that there is an interest in this kind of content when presented in the Gardens, yet finding the ideal delivery strategy remains challenging.

Identifying the "smartphone wall" is only the first step towards understanding how to incorporate visitors' hardware into interpretation strategies and visitor services. The Kew Gardens Official App has proven to be a successful wayfinding tool (Waterson & Saunders, 2012), and this study does not rule out the value that smartphones can have as part of a stimulating mix of activities with which to interact. Future work must be conducted to better understand the "smartphone wall" and to find ways to overcome its limitations. As audiences and technologies evolve together, new practices will emerge and more fluid integration will be achieved. For now, being at the frontier of these new practices raises many unanswered questions. The only way to gain insight into these challenges is by continuing to analyze and scrutinize our technologies and the way they blend with our visitors' daily practices. So, are smartphones worth their cost, can we translate the potential into practice? It's probably too soon to know.

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7. Appendices

Appendix A: Influences to visit the Royal Botanic Gardens, Kew

About visitors and their needs		About Kew Gardens	
I enjoy plants and/or gardens	35%	To see the gardens generally	50%
Just for fun	28%	Kew Gardens is a beautiful place	29%
Going for a walk	24%	Kew Gardens is one of the sights of London	18%
Somewhere to visit in good weather	12%	Kew Gardens is peaceful/relaxing	15%
Others in the party wanted to visit / Showing Kew to others	11%	Kew Gardens is an important part of British Heritage	8%
Somewhere to relax	11%	Kew Gardens is a very important botanical garden/World Heritage Site	4%
It's been a while since I last visited	8%	Kew Gardens is a unique and special place	4%
Somewhere to take the children	7%	To see particular areas of Kew Gardens	3%
To learn more about plants and/or gardens	6%	Festival/temporary exhibition	1%
Just in the area	6%	To see particular plants	1%
I am interested in conservation	5%	To attend a special event/activity/tour	< 1%
Professional interest in plants and/or gardens	3%	Kew Gardens' conservation program	< 1%
I visit Kew Gardens Regularly	3%	Other	2%

Appendix B: Visit outcomes at the Royal Botanic Gardens, Kew

As a result of my visit to Kew Gardens today, I feel that Kew has helped me…	**Agree strongly**	**Agree**	**Neither**	**Disagree**	**Strongly disagree**	**DK**
to become more interested in plants than I was before	5%	37%	43%	13%	1%	1%
to know why saving plants and plant environments is important	10%	33%	42%	13%	1%	1%
to understand about Kew's work in the UK and overseas	8%	31%	45%	15%	1%	<1%
to learn more about the work of Kew's Millennium Seed Bank	5%	24%	48%	19%	3%	<1%
to take away practical ideas I can try at home	4%	27%	46%	18%	3%	2%
to help me feel I or my children have learnt something	4%	29%	37%	13%	7%	11%
to see that scientists discover new plants and new uses for plants every day	2%	36%	43%	16%	2%	1%
I do not feel I have learnt anything as a result of my visit	1%	6%	18%	16%	56%	2%