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CHIMERA

Supporting wearables development across multidisciplinary perspectives

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CHIMERA: Supporting Wearables Development across Multidisciplinary Perspectives

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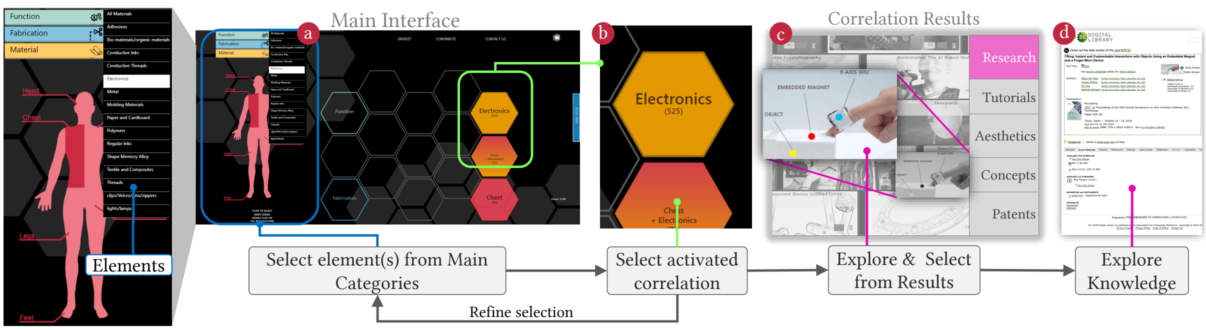

Fig. 1. CHIMERA interface workflow, left to right: a) Categories and Elements to correlate search criteria. b) activated hexagon correlation blocks. c) Correlated Search Results interface. d) an online resource redirected to from CHIMERA's database.

Wearable technologies draw on a range of disciplines, including fashion, textiles, HCI, and engineering. Due to differences in methodology, wearables researchers can experience gaps or breakdowns in values, goals, and vocabulary when collaborating. This situation makes wearables development challenging, even more so when technologies are in the early stages of development and their technological and cultural potential is not fully understood. We propose a common ground to enhance the accessibility of wearables-related resources. The objective is to raise awareness and create a convergent space for researchers and developers to both access and share information across domains. We present CHIMERA, an online search interface that

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allows users to explore wearable technologies beyond their discipline. CHIMERA is powered by a Wearables Taxonomy and a database of research, tutorials, aesthetic approaches, concepts, and patents. To validate CHIMERA, we used a design task with multidisciplinary designers, an open-ended usability study with experts, and a usability survey with students of a wearables design class. Our findings suggest that CHIMERA assists users with different mindsets and skillsets to engage with information, expand and share knowledge when developing wearables. It forges common ground across divergent disciplines, encourages creativity, and affords the formation of inclusive, multidisciplinary perspectives in wearables development.

CCS Concepts: • **Human-centered computing → Ubiquitous and mobile computing**; • **Applied computing → Enterprise ontologies, taxonomies and vocabularies**.

Additional Key Words and Phrases: taxonomy; database; visual search; Wearables; multidisciplinary

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1 INTRODUCTION

cWorking across disciplines is fundamental to developers and designers [38]. However, it can be challenging as experts from different disciplines struggle to align perspectives—their mindsets, knowledge sets, skill sets, and tool-sets—when they lack shared priorities, assumptions, vision, or simply the means [7]. Communicating critical knowledge can be difficult [41], and lead to gaps or breakdowns in values, goals and vocabulary, in turn reducing and even preventing collaborations. Such challenges are exacerbated when technologies are in the early stages of development, and their technological and cultural potential is not yet understood.

The field of wearables—where many disciplinary perspectives converge—is exemplary. Wearables is a burgeoning research area, and the challenges and opportunities of developing wearables within a common ecology are not well known. Teams with core expertise in fashion and textile design may find the underlying technology in wearables bewildering. Developments in clothing processes may similarly be relatively unknown to HCI and engineering fields.

Wearables require the convergence of multidisciplinary practices that are typically developed independently. These practices may be driven by diverging values and be challenging to align toward a common goal. However, it is necessary to integrate these fields if we are to develop wearables that afford functional, comfortable, and aesthetically enriched interactions [12, 48]. To achieve this integration, the divergent perspectives and practices used within wearables research must be made accessible, understandable, and navigable across disciplinary divides. We propose that this shift would benefit the design process by better positioning designers and developers to address challenges in wearability, manufacturability, durability, and interconnectivity. [12]. This paper proposes a common ground for multidisciplinary perspectives to enhance awareness, accessibility and readability of wearables-related resources for researchers, developers, and designers.

To achieve this vision, our team—of engineers, industrial, fashion, and interaction designers developed a Wearables Taxonomy; a database of research, tutorials, aesthetic approaches, concepts, and patents; and CHIMERA, an online interface that provides visual and taxonomic connections to the growing database. In a preliminary study, we observed a fashion designer and an engineer as they developed wearable sensors, then conducted two workshops on wearables design. These studies revealed communication barriers across multidisciplinary backgrounds, fragmentation in vocabulary, and lack of awareness of practices outside each practitioners' discipline.

Our Wearables Taxonomy is a response to this fragmentation. It's purpose is to assist users in accessing knowledge from divergent perspectives that contribute to wearables development. CHIMERA then provides the means to navigate a curated database using the taxonomy. It is a dynamic, visually rich online search interface that presents an organised and manipulable view of the taxonomy. CHIMERA follows the principle of a reverse dictionary [53]. Users describe a concept with the taxonomy, and CHIMERA provides a curated collection of wearables-related research, tutorials, aesthetic approaches, concept designs and patents, based on user-selected phrasing of interest points. This approach overcomes critical obstacles, such as communication issues between specialist areas, knowledge exploitability, and dissemination in multidisciplinary collaborative environments, by providing an interconnecting, navigable and explorable vocabulary.

We refined the taxonomy and CHIMERA with input from a diverse range of experts, which helped us streamline the taxonomy, improve terminology, and reorganise the visual presentation of categories. A user study between CHIMERA and a baseline interface (a search engine) involving designers with varying backgrounds and expertise revealed that CHIMERA helped participants focus their searches when they felt stuck, and the taxonomy helped them to obtain search terms that were logical and useful. In contrast, participants *not* using CHIMERA reported difficulty in translating their intent into appropriate search terms. Additionally, participants using CHIMERA showed increased exploration of content and greater production of designs outside their disciplines. Finally, we used CHIMERA with students in a third cycle wearables design class to corroborate changes, improvements and its validity in a multidisciplinary educational setting. The resulting taxonomic search interface—CHIMERA—promotes multidisciplinary development, enhances how designers link resources, and creates connections within a fragmented field through a knowledge base that is designed to grow and be sustained by the wearables community.

In summary, our contributions are:

- A taxonomy of wearables to classify and integrate common practices and principles and allow multidisciplinary access and communication.
- A growing database of **842** wearables-related content, including research, tutorials, aesthetics, concepts, and patents that uses the taxonomy for its organisation and classification.
- An online interface that aids visual exploration of the database, and provides a novel navigation technique to search, discover, access, and filter multiple sources of wearables-related information.

In this article we describe related work on multidisciplinary collaboration, search interfaces, databases, and taxonomies. We present our two-part preliminary study that allowed us to identify common issues of the wearables development process and define the taxonomy. We unpack the taxonomy development process and describe the methods used to define a language and classification system for wearables. We explain the development and function of the CHIMERA search interface, highlighting features that make this interface unique. We then report our three-step evaluation process and findings: a multidisciplinary design task, an enquiry to experts working with wearables, and a study in the wild with a wearables design class. To conclude, we discuss how our work contributes to expand knowledge awareness, encourage curiosity, enable accessibility, and promote the inclusion of multidisciplinary perspectives in wearables development.

2 RELATED WORK

2.1 Knowledge Sharing

Creativity and innovation often requires work that spans disciplines [15, 33, 54]. Access to a broad scope of knowledge is at the core of leading developments in industry, technology and education [31, 33, 42].

Research in the domains of haptics and human food interaction demonstrates how interactive data visualisations afford ongoing community engagement, contribution, and curation [6, 50].

In a field as dynamic and heterogeneous as wearables, how information is represented in a database may not align with how others understand it [11, 50]. Within this landscape, researchers note how the impact of communication problems, knowledge disparities, and a differing set of assumptions for common terms can inhibit the success of multidisciplinary development [11, 26, 66]. Wearables are no different [36, 41, 48, 52].

CHIMERA democratises access to multidisciplinary knowledge that underpins wearables development to afford developers, researchers, and designers better access to information across domains. CHIMERA addresses this knowledge accessibility and distribution in wearables by lowering the barrier presented by discipline-specific jargon and centralising the information.

2.2 Interface and Databases

A range of technologies supports information search. Most online platforms such as Google™, Pinterest™, and Behance™ are databases that guide open search using user input and user-related stored data. Specialised databases exist for research such as patent applications [26, 50, 66]. Tutorials and concepts on open-source websites (e.g. Adafruit [1], Sparkfun [55], Instructables [30]) provide step-by-step instructions using vivid and detailed descriptions and images to capture a larger variety of users. These resources simplify and inspire the information search while encouraging a snowball of possibilities and ideas [64]. Effective visualisation enhances resource use while navigating interfaces [20], but such tools are constrained to the limitations of user knowledge and vocabulary [60]. Further, due to the sheer volume of information available and variability of the search, audience searches are typically incomplete. [14].

CHIMERA responds to this challenge by distributing information according to the user's objective. The CHIMERA interface structure assists novice and expert users to access the information through a taxonomy-based filtration process and an understandable context.

2.3 Taxonomies

A taxonomy is the process and result of categorisation of concepts or objects in a domain. To develop a taxonomy involves literature reviews, author knowledge and community input. In design, it also requires in-depth analysis of design examples. The purpose of this work is to produce a list of categories and elements that may be used to organise and classify the information, such that people with different backgrounds may label and access it [23, 50]. A Taxonomy must account for the scope of concepts, practices, processes, and vocabulary within and across disciplines and understandings in purpose and development choices. DataTone [24] and Rico [18] highlight the need to disambiguate language used by authors, to allow a complete understanding of what a person might mean as they search for similar data or designs. In "The Elements of Fashion Style," Vaccaro et al. [61] highlight language differences across fashion that frustrate users searching for outfit combinations. Recent wearables-related taxonomies span trends in design use and aesthetic experience [40], co-experience support [39], body placement zones [59], gestures [58], ergonomic comfort and wearability [25, 67], virtual and in-person interactions [9, 17], and privacy and user interactions [43, 47].

Alternative methods to generate taxonomy attributes usually orient towards a specific domain [21]. A compound taxonomy or classification of information integrating different backgrounds into their development is underrepresented and complex to develop. Crowdsourcing is one alternative to alleviate the complexity of integrating different perspectives and vocabularies into a taxonomy [8, 13, 56]. Our Taxonomy integrates the multidisciplinary vision of developers, researchers, designers, and enthusiasts. It factors in users' vocabulary, practices, and perspectives. Additionally, it consolidates the literature in a shared environment that affords an equivalent understanding of the content to all users independent of their level and field of expertise.

2.4 Multidisciplinary Perspectives in Wearables

The integration of fashion into HCI is a clear example where social and cultural practices enrich interactions and technology to allow cross-pollination of disciplines and industries [36]. Pan and Stolterman [**?**] draw from fashion thinking [46] and the social effect of fashion [34] to examine how notions of 'fashionable' impact HCI research, methods, approaches and skills. When approached as an alternative lens for HCI, fashion opens the door to under-reported challenges and opportunities. It accommodates 'subjective, aesthetically-oriented' criteria, in parallel to scientific aspects. Moreover, fashion research radically rethinks notions of materiality, embodiment

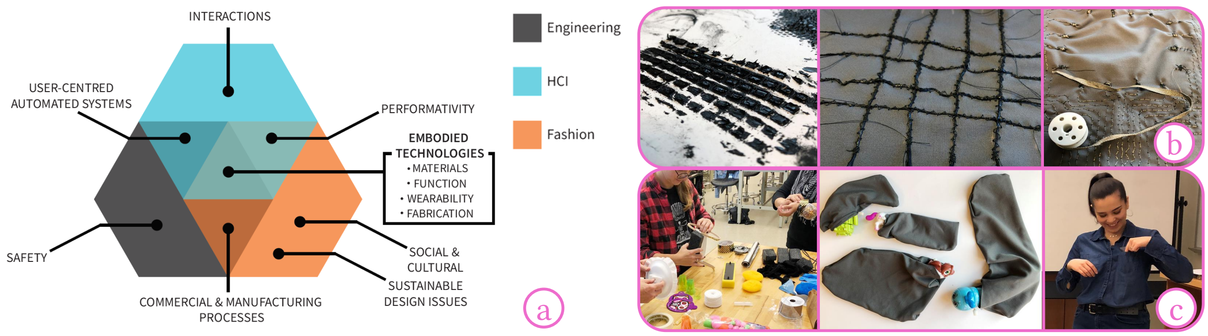

Fig. 2. a) Example of wearables common attributes between multidisciplinary domains, b) e-textile material fabrication, c) Haptic objects built using wind-up toys, an embodied design exploration of wearability.

and wearability in wearables development [37, 63]. The convergence of Fashion and HCI in wearables affords new ways of thinking about how technology and textiles might interplay and inform each other, during the development process, as well as in the final product. It is common for researchers exploring multidisciplinary prototyping tools to aim to integrate design and technical options early in the ideation process to enhance clarity in communication across fields [51]. Wearable Bits highlight how programming, stitching, or hardware prototyping limit designers to integrate new fields [32]. Limitations also affect multidisciplinary workspaces where gender, race, and socioeconomic contexts are influential [5, 45]. CHIMERA uses a multidisciplinary concept to build a taxonomy that will assist researchers, developers and designers to disrupt hidden biases and extend reach.

3 PRELIMINARY STUDY: TOWARDS A WEARABLES TAXONOMY

To develop our taxonomy, we first needed to identify critical aspects across different disciplines that designers and developers consider creating wearables. We conducted an initial set of studies: an e-textiles-led inquiry and a series of design workshops.

3.1 E-Textiles Inquiry

Over one month, two of the authors—a fashion designer and an engineer—fabricated sensors using a combination of textiles, polymers, and electronics. They began by cross-listing fashion, textile and engineering design concerns, then used e-textile material fabrication as a dialogue to ground concepts and terminology across disciplines. They collected notes, design logs, design samples, prototypes, and photographs of the process; categorised the materials, properties, and characteristics for each e-textile; and analysed them using an inductive approach. A key finding was that misalignment of principles hindered communication, and material processes were an obstacle to fabrication. For example, compatibility of sewing and stitching with miniature electronics, soldering flexible connections, needle holes in machine-sewn electronic circuitry, and the potential to use the entire body as a canvas for sensing. We identified the need to standardise shared terms, improve the description of objectives that motivate each field, and define a first level of a vocabulary to describe aspects of methodology, material, and fabrication procedures that may be required in wearables development but are not yet known or well understood. We then transitioned from studying wearable devices and materials in the lab to study them in context with users.

3.2 Exploratory Design Workshops

To focus our findings from the previous study towards embodied experiences of wearables, we conducted two workshops with 10 participants from a range of backgrounds, including dance (2), theatre (2), time-based media

(1) and interaction design (5). The participant group was selected to contribute insight into wearables design for movement, and the performance of body-worn interactive devices in social situations. The workshops employed bodystorming [49] to imagine narratives for physical-virtual scenarios, and other embodied design ideation techniques [65], including rapid prototyping with off-the-shelf technologies [62] (see Fig. 2c). Attributes such as wearability, size and application guided this set of workshops. Video recordings, pre-workshop surveys and participant dialogues were thematically analysed to reveal ideation needs, descriptive language, and curation requirements for a shared understanding of wearables. This process helped us identify how participants build on everyday experiences to develop wearables through: 1) gestures, 2) conversations, 3) speculating with objects, 4) prototyping, and 5) interactions. The approaches align with the Embodied Design Ideation methods described by [65] that we used in the workshop and suggest that phenomenologically informed design methods may assist people in (re)thinking and (re)imagining how they engage with the world in ways that are rich and informative.

For example, workshop participant (WP)5 reimagines an everyday accessory with novel functions and refined materials, *"I never liked ties…I would like to replace the tie with something like this. And this one would be the sensor, or the phone, or music. So I can out put here my pods and listen to music or just communicate with someone. Or else it could be a microphone? And the gold … this would be for aesthetics!"*. WP7 highlights the relationship between materials and fabrication, *"I don't like this cord, it needs a little bit more weight to it. So I wish that it laid flatter that would go with the geometric look ...I ripped here but then reinforced it with this duct tape and I think the pattern really complements the rest of it so that was a happy accident. I like long pendants."* In contrast, WP6 communicated wearability through posture and gestures, *"When I was walking around it felt like a medallion, felt regal, I was puffing my chest… "* The workshop illustrates how foregrounding *material-function-fabrication-body zones* can contribute to the making of wearables. We observe dance and theatre participants articulate material embodiment tasks with bodily attunement, while interaction designers related technical needs of their design, by envisioning functions (sensors) and fabrication. These insights clarified our design requirements and intersecting vocabulary across a variety of disciplinary backgrounds. They informed the gap in research of a taxonomy tailored to the concerns of common vocabulary, technical needs, and the features designers found important for their designs; expanded our knowledge of embodied technologies and highlighted the importance of dynamic, embodied, and context-aware prototyping during the wearables design process.

3.3 Finding Common Attributes

In the preliminary studies, we observed a strong correlation between aesthetic concerns, cultural influences, functionality, and preferred body locations. This interplay informed the need to establish a visual architecture that dynamically correlates these categories and provides knowledge to fulfil these needs.

The e-textiles inquiry assisted us in identifying the first level of intersecting motivations, practices and principles. This interplay informed a visual architecture that dynamically correlates categories necessary to our taxonomy, and vocabulary namely, materials, fabrication, and end-use for wearable projects common across disciplines. The design workshops revealed crucial challenges when working in the space of disciplinary complexity, namely (1) achieving commonly held objectives and goals in practice, (2) sustaining shared motivations, priorities, principles, processes, and tasks, and (3) body as a central influence in the design and creation process. The workshops informed body-zones of wearability that are not only biomechanically functional but aesthetic in terms of fashion, social norms, and codes. These challenges also indicated a core level of information across disciplines that should be reflected in a knowledge database to fulfil these needs. Participants engage in four necessary design actions that assisted in defining a dynamic pipeline for wearables design. This pipeline fulfils four categories that designers repeatedly perform, independent of their starting point. For example, a designer might be interested in types of manufacturing and production methods, or an artist searching on materials for aesthetic purposes

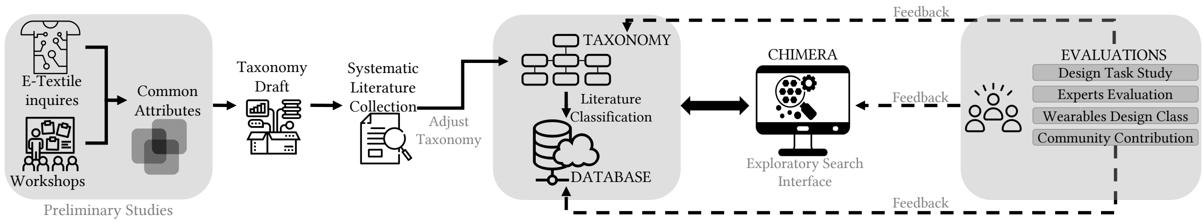

Fig. 3. The development process of CHIMERA—Starting from e-textile explorations and participant workshops (left) to build our Taxonomy, database and interface (center), evaluations and feedback (right)

beyond mechanical functionality. These challenges orient us to define the classification of the content in terms of objectives, motivation, principles, and practices.

We used thematic analysis to centralise and categorise the information collected from the inquiry, workshops, and data collection and generate four main categories—Function, Fabrication, Materials, and Body Zones—for a hierarchical organisation of terms, practices and concepts related to wearables. This iterative process resulted in the initial set of categories and elements. With the initial categorisation, we started collecting previous wearables design work to ensure the groups fit the literature in parallel to this classification process. The initial groups of vocabulary were expanded and reorganised using the collected literature. Categorising the literature provided an additional vocabulary that built on the findings from preliminary studies. During the analysis, the categories and elements were confirmed, and new ones were created. The final four main categories and fifty-nine elements resulted from the iterative organisation and classification process of the data collected and analysed during the preliminary studies and the wearables literature collection. The evolution of the taxonomy was directly connected to the continuous database population. This structure was designed to allow developers from different fields to cross-fertilise expertise without having to venture far from their area of specialisation. The process was critical to articulate core categories necessary to balance our taxonomy, clarify design process requirements, and create the First Draft of our Taxonomy framework. (Fig. 3)

4 WEARABLES TAXONOMY

A taxonomy is usually created through an in-depth systematic review of research literature [50]. However, creating a taxonomy becomes challenging when the diversity of backgrounds and approcaches is too large. This diversity raises issues, such as a lack of shared terminology that may cause misunderstandings in meanings, concepts, or attributes. We addressed this challenge using an end-user-focused approach, identifying the people who will use the taxonomy and using them to drive the content that the taxonomy will include [10, 28]. Through the preliminary studies (see Sec. 3), we identified common terminology, practices, and attributes across the identified disciplines and created the following categories that can broadly be used to disambiguate the common terminologies.

Function: Applications, roles, operations and interactions afforded by the technology.
Fabrication: Implementation methods.
Materials: Components, objects, substances and elements, modified through fabrication.
Body Zones: Locations for placing wearables.

The main Categories contain a global perspective of the vocabulary and practices, arranged into domains or subgroups that we name *Elements*. Each *Element* represents a generalised term that reflects a specific principle or practice inside a *Category*, understandable to the variety of backgrounds involved in wearables. There are fifty nine *Elements* distributed across the categories. Using the elements included in the first draft of our taxonomy, we initiate the collection of resources systematically. We iteratively refine our taxonomy by discussing and

Table 1. A categorisation of the terms used to tag content in CHIMERA and how they map to the four main categories of Function, Body Zones, Fabrication, and Materials. Example tags shown above are representative and not comprehensive.

Categories	Elements	Example Tags
Function	Aesthetics	Artistic, beauty, art
	Breathability	Porous, evaporation
	Cognitive	Emotion, reaction, mental
	Control	Command, automation
	Display	Screen, highlight
	Electronic Connections	Contact, conductivity, bonds
	Emissivity	Glow, radiation
	Energy Harvesting	Solar panels, static energy
	Feedback	Haptic, olfactory, visual
	Gestures	Pinch, turn, grasp
	Interactions	Touch, press, hold
	Interfaces	touch, graphical, user interface
	Modularity	Parts, models, templates
	Morphology	Change, shape, structure
	Movement	Dynamic, stretch, compress
	Protective	Security, isolation, insulation
	Sensing	Capacitive, temperature
	Skins	Tattoos
	Storage	Physical, data
	Studies	Reviews, surveys, application
	Wireless Com.	WiFi, Bluetooth, radio frequency
Body Zones	Head	Helmet, smart glasses, make-up
	Chest	Necklace, blouse, shirt
	Back	Backpack, jacket, vest
	Arms	Sleeve, armband
	Hands, Wrist	Glove, wristbands, smartwatch
	Pelvic region	Smart/ safety underwear, belt
	Legs	Tights, pants, skirt
	Feet	Smart shoes, socks, sandals
Fabrication	3D Printing	Additive manufacturing
	Embroidery, Applique	Embellishment, needlepoint, beading
	Heat Transfer	Vacuum forming, pressing
	Knit	Interlink, knot, crochet, lace
	Laser Cutting	Digital fabrication, segmentation
	Layering	Layers, coating
	Machining	Lathe, table saw, mill
	Moulding, Casting	Sand moulding, shell mould, plastic mould
	Painting	Spray, brush, dipping
	Pleating, Folding	Origami, Fold, bend, flex
	Printing	Screen printing, inkjet printing
	Soldering	Solder, brazing
	Sticking	Joining, holding, gluing
	Stitching	Stitch, cross-stitch, sew
	Weaving	Interlacing, braiding
Materials	Adhesives	Liquid adhesives, tape, silicon
	Conductive Inks	Silver, carbon, nickel
	Conductive threads	Stainless steel, gold yarn
	Electronics	Sensors, motors
	Hardware	Zipper, pins, rivets
	Illumination	LED, bulb, reflector
	Metal	Silver, gold, aluminium
	Moulding materials	Plaster, clay
	Organic materials	Bio-design, bacteria, e-coli
	Paper, cardboard	Cardstock
	Polymers	Pedot:PSS, silicon, rubber
	Regular links	Paint, fabric paint, colour
	Shape memory alloy	Wire actuator, smart metal, muscle wire
	Textile, composites	Silk, nylon, cotton
	Threads	Yarn, fiber, string

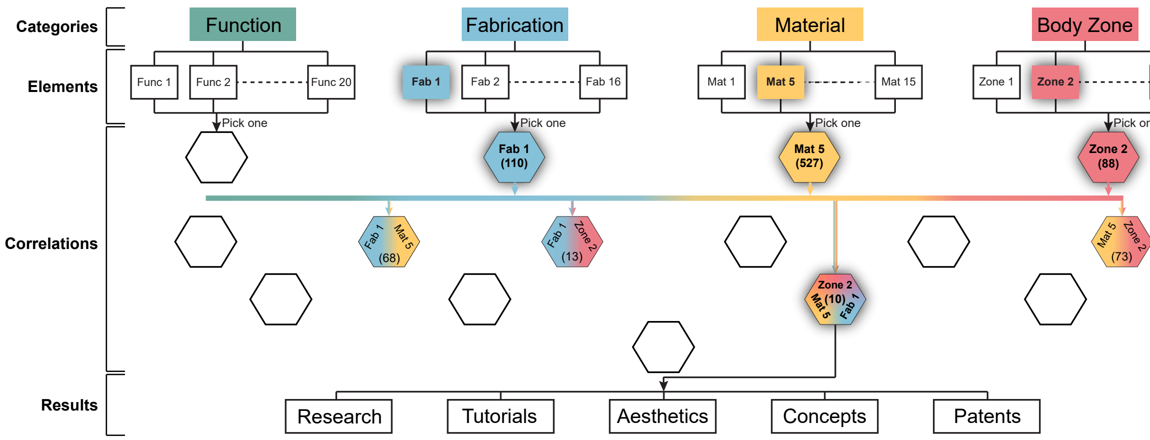

Fig. 4. Hierarchy of the taxonomy categorisation, sub-categorical Elements and correlations—Data sequence of a search in progress in the CHIMERA interface

examining each resource added to the database. To ensure the coherence of terminology across disciplines, we used team consensus to group the terminology extracted during the preliminary studies, refinement, and evaluations described in section 7 (Table. 2). From the evaluations, we note that users found it difficult to parse the amount of information displayed. To mitigate this issue, we implemented a third level classification, resulting in grouping types that afford easy parsing of resources. The group types (see bottom of Fig. 5right for context) are as follows:

Research: Scientific approaches to wearables.
Tutorials: Step-by-step procedures explained as instruction sets, lists, descriptions or video.
Aesthetic approaches: Works oriented towards art, theatre, dance, performance, and sensory perception.
Concept Designs: Ideas not yet developed, tested or taken to market.
Patents: Registered patents

The resulting Taxonomy—of Categories, Elements and Grouping Types—affords common ground across disciplines, contributes to the cross-fertilisation of practices, and hierarchically organises the database.

5 DATABASE

For the initial data collection, three authors (with backgrounds in HCI, fashion, and engineering) collated literature across ACM and IEEE journals, ACM conferences, Google and WIPO patent websites, artistic websites, and instruction-based websites (e.g. Arduino, Instructables, Kobakant). Information was collected systematically using keywords such as "wearables + *Elements*" from our developed taxonomy. The authors thus found resources, and discussed how to categorise them. The title, links, authors, descriptive images, year and venue for each resource were then manually compiled. The goal was to ensure a holistic and sufficiently diverse database to demonstrate how CHIMERA might serve potential users, and for future studies.

Our database currently has 842 manually-added resources, including 600 research papers, 81 tutorials, 103 aesthetics, 18 concept designs, and 45 patents released mainly between 2010–2020. On the main interface of CHIMERA, we provide a “contribute” button to enable peer review and community collaboration. Providing community access helps to ensure that the database remains robust and comprehensive. Users can suggest authors, websites, projects, and re-categorisation of existing content. Following a curation process, approved sites are added to the growing database. CHIMERA presents cited data for non-commercial, educational knowledge

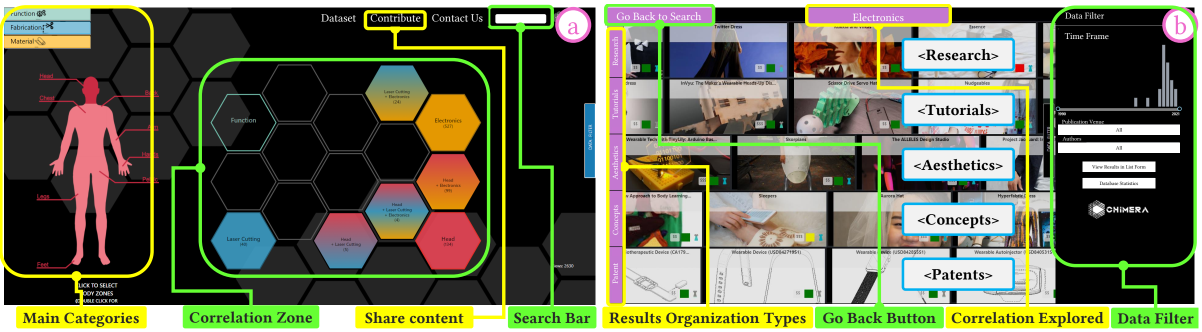

Fig. 5. a) CHIMERA Interface: Main Categories, Correlation Zone, Content Sharing, Data Filter. b) Chimera Resources Interface: Results Organisation Types, Go Back Button, Selected Correlation, Data Filter.

distribution purposes only. The interface links to external sources. If a website requires payment, CHIMERA simply provides a link to the site.

6 CHIMERA WEARABLES EXPLORATION ENGINE

In Greek mythology, a chimera is a creature that combines three distinct animals. Our interface, CHIMERA, is an exploratory and visual search engine that combines wearables documentation across multiple disciplines. A visual search interface allows users to search for information quickly and effectively. It aims to remove barriers posed by knowledge and vocabulary when searching for information [19]

Inspired by Altarriba et al.'s Human-Food Interaction Literature Review App [6], CHIMERA facilitates diffractive reading of works from diverse sources—inspired by the notion of diffraction in physics; the intention is to map interference, rather than reflection, or reproduction [3, 4, 27]. This approach makes differences visible in ways that afford rapid and easy identification of research opportunities. It maps divergent perspectives in the same database, accounting for interference across disciplinary perspectives, practices, and values. As a result, this process better positions researchers to challenge their assumptions and embrace other perspectives [6].

CHIMERA uses the taxonomy categorisation as the search and organising logic. It provides navigable access to a growing database of multidisciplinary wearables-related research, tutorials, aesthetic approaches, concept designs, and patents. We now detail the design, underlying logic, and workflow of the CHIMERA information architecture.

6.1 Visual Architecture – Main Interface

The CHIMERA Main interface is illustrated in Fig. 5 left. Its purpose is to allow users to access information about wearables. The categories and elements serve as a method for selecting and filtering content from the database. The principle features of the *Main interface* are the following:

Main Categories: On the left side of the main interface (Fig. 5 left and Fig. 1a), each category enables access to a drop-down menu that contains the *Elements*(the second level of the taxonomy). The *Body Zones* category uses a body-shaped image as a structure, where the user clicks over the desired body part to activate related *Element* selection.

Correlation Zone: The Honeycomb structure located in the centre of the main interface provides access to the database resources (Fig. 5 left). The *Elements* selected by the users will appear inside a hexagon of the correlation zone. The system will use the zone to display the selections and the correlations/combinations of the elements to filter the resources. The users can select any of the fifteen combinations (Hexagons) to access the information available that will be displayed in the *Resources Interface* (Fig. 5 right). The honeycomb configuration represents the second level of filtering provided by the taxonomy to facilitate information readability. The correlation between all fifty nine elements provides up to 20 million search options/combinations that users can select from.

Contribution button: This button enables designers and developers to expand the database and share resources with the community using CHIMERA.

Data Filter: assist users reducing the volume of resources that will appear on the Database interface (Fig. 5 right) using metadata such as the year, authors, and source/venue.

6.2 Visual Architecture – Resources Interface

Users of CHIMERA select search categories and elements. These appear grouped in the hexagons at the centre of the screen. To launch the search query, the user clicks on the relevant hexagon, and the screen jumps to the *Resources Interface*, which displays the corresponding resources, randomly ordered within the defined groupings of the taxonomy (Fig. 5 right). The Groupings appear as horizontal carousels, emerging from the left side of the interface. Each carousel represents one of the five grouping types defined (Research, Tutorials, Aesthetics, Concepts, Patents). CHIMERA uses images to facilitate navigation of the search results. The images representing each result are clickable links to the original website resource. Users browse these images by scrolling the carousels and clicking to access detailed information from the source. The horizontal carousels use the same navigation principle implemented in most video streaming services. Overall, the workflow enables the idiosyncratic, detailed, and diffractive reading of searched data.

7 EVALUATION

To validate and ensure that CHIMERA, our Taxonomy, and the database capture the multidisciplinary perspectives of wearables users and stakeholders, we collected users' perspective with varied backgrounds and expertise levels. Our evaluation had a three-step process. We conducted two sets of evaluations: 1) a multidisciplinary design task, and 2) an enquiry to experts working with wearables. These studies provided comments, insights and perspectives on the taxonomy, database and CHIMERA. We analysed this data to refine the taxonomy and improve CHIMERA and the database. We then conducted 3) a study in the wild with multidisciplinary students of a third cycle wearables class. Our objective was to corroborate our previous analysis and validate the changes advised from expert perspective, with novices. We detail these studies.

7.1 Multidisciplinary Design Task

7.1.1 Recruitment: We recruited 24 participants from our professional networks: 13 self-identifying as females, 11 as male (ages: 22-45 years). We recruited diverse nationalities and a range of disciplinary backgrounds, ranging from one to ten years of professional experience, not all with wearables. We collected four types of data: user background information (survey); navigation patterns (video recording); design logs (sketches, and notes); and survey and interview responses.

7.1.2 Study Design: We conducted a two-part study across Germany and the United States. Phase 1 involved a 20-minute design and ideation task; in phase 2, participants had an additional 20 minutes to develop one of the designs they had proposed in Phase 1. An ideal brainstorming session will range between fifteen to thirty minutes [16, 22]. The times in our study were defined to avoid fatigue and maintain productivity during the sessions.

To locate participants' disciplines on the wearables spectrum, we collected relevant information—such as current occupation and prior or ongoing wearables-related projects—via a survey. Participants were randomly placed into a Control Group (CG, 12 participants) and an Exploratory Group (EG, 12 participants) , without being told that there were groups. We provided ideation and design development resources to both groups: internet access, sketching materials, body part templates, colour markers, tracing paper—to enable participants to search out, draw, sketch, write, or list design concepts and ideas. The EG was, additionally, given access to and trained how to use the CHIMERA online interface.

7.1.3 Study Procedure: Participants followed a two phases process.

Phase 1: Task: Ideation (20 minutes): *Conceptualise as many wearable ideas as possible using the given materials. To stimulate ideas, you may design for the year 2030, and link unrelated concepts for possible technologies. We consider a a valid design for this phase, any concept that specifies a body part and a function, with as many details as possible.*
This task was an open-ended activity. All participants had the same instructions, and the general requirement was to design wearable devices. The difference between groups was that EG had access to CHIMERA. The objectives were to understand the potential of CHIMERA and the Taxonomy for accessing information in the ideation process; to observe areas of improvement, and ascertain if users explore beyond their current knowledge base.

Phase 2: Task: Design development (20 minutes): Develop one of the Phase 1 concepts into a more detailed design. You may modify the original design in any way. Please specify material, fabrication techniques, and form factors.
The objectives of this task were to understand how useful the taxonomy and interface are in providing access to more detailed information; how far users might go beyond their current knowledge base; whether CHIMERA was useful; and what characteristics contributed to the quality of use.

7.1.4 Design Task Results: We begin by describing the rationale used to define the comfort zones of the participants in the EG and the CG, and add the insights collected from the CG. We then summarise the findings from the thematic analysis of the data collected during the study in five themes: Taxonomy, Database, Interface, and Changes to CHIMERA.

Comfort Zones: We collected information from Design Task participants about *years of experience and number and type of wearables-related projects* that might incline them towards a particular field. We used this data to label our participants in a more dominant area of expertise, and to observe the influence of background in the search patterns and design logs.

Control Group (CG) Insights: Using thematic analysis, we identified that the designs and vocabulary used in searches relied mostly on participants' background knowledge. The search pattern across CG participants was a generalised combination of words on the search bar, not always using wearables terminology (i.e. *"nice architects"*, *"making capsules for the poor"*, *"video recordings"*). Most participants fixated around a single topic using different combinations of words during the search, which later reflected in the level of details in the design logs. 11 out of 12 participants reported how they felt their lack of knowledge limited their designs. Similarly, CG participants (11/12) noted how difficult it is to transfer their thinking into words and opted to explore using image-based engines such as Pinterest and Google Images. In the CG, we observed how language barriers limit understanding when participants approach unfamiliar fields of knowledge, limiting access to new information, and hindering cross-disciplinary communication [2, 35]. This discovery enabled us to create a baseline for our experiment about their search methods and the amount of data accessed.

Taxonomy: Participants of EG reported that the organisation of CHIMERA helped them to orient their searches when their ideas became blocked. They note how the taxonomy helped them obtain 'logical' and 'helpful' searches and contributes to smooth and productive search navigation. Participants mentioned how excited they were to find different, unexpected results from divergent disciplines. Fig. 6 displays the high amount of information searched and explored during the design tasks. EG04 found the correlation

Table 2. Results Comparison between Exploratory Group (EG) and Control Group (CG).

Comparison Area	Exploratory Group (EG)	Control Group (CG)
Vocabulary / Knowledge Accessibility	No specific vocabulary was needed to access available curated information.	Searches are limited to background knowledge and ideas. Participants used a generalised combination of words to access information. Vocabulary was not always related to wearables.
Number of Designs	Mean = 7.25 (SD = 5.17) - Modal value: 2 (3 times), 8 (3 times), Total concepts = 83	Mean = 4.67 (SD = 3.14) - Modal value: 1 (3 times), 2 (2 times), Total Concepts = 56
Knowledge Awareness	Participants mentioned how excited they were to find different, unexpected results from divergent disciplines.	Limited knowledge on other topics limited the information access and ideation.
Search Methodology	EG used the general idea or objective to identify solutions. Participants navigated fast through information, allowing them to access multiple curated resources.	CG had to navigate information, explore options, and select alternatives. The groups commented that it is complicated to filter and verify all that information quickly.
Data Accessed	Detailed, filtered, and curated data. EG accessed large number of resources (Fig 6).	Random searches to generate ideas. Participants were not sure if results will be useful. CG accessed a limited amount of resources (Fig. 6)
Similarity	Both groups preferred Visuals navigation and image based search engines to access information.	

principle helpful and said that "They're like Venn diagrams but hexagons instead. Find overlap between categories." The taxonomy in the correlations for the initial search also helped participants to scope down the data entries and segregate the ideas into various more specific sections (EG05, EG06).

Database: Credibility, reliability and trust in the information available was a significant concern shared across participants during the evaluation. CG01 explains, *"I would like to have a better idea of what websites are credible and which are not. I think that is always the biggest struggle when searching online"*. Whereas, CG03 states, *"Accessing best resources has never been a problem, but this usually restricts and slows my design process"*. This depiction of the volume of content reveals what consumes valuable time while searching for information. CG03 further attributes their search inefficiency to the amount of *"pseudo-science and unreliable papers that are available online....Perhaps some of the information is anecdotal, or the science behind it can be not so solid. Therefore those sources can not be relied upon."*. These quotes demonstrate the contradicting challenges people reported while searching information. A well-curated database fulfils these needs as a source of efficient and clear content. CHIMERA allows users to reduce the attention on the search and focus in on design tasks. Our EG confirmed these observations. EG09 comments *"I believe that the CHIMERA can streamline searches relating to design that would normally be difficult to search"*; EG01 describes how the *"Suggested categorization helps a lot to discover and search things"*. These responses emphasise how our participants appreciated the ways in which information is easily utilisable through CHIMERA's categorisation and knowledgeable curation.

From the design logs, we were able to identify how the information accessed on the database enhanced the designs created during the evaluations. Participants reported that they would be willing to share projects and resources with CHIMERA and contribute to the knowledge distribution and creation of a wearables virtual community. The expert survey confirmed this statement and provided suggestions and ideas on resources and methods to enhance the database. One expert researcher commented, "I love the chimera interface, and I believe that it can become a useful tool if anyone can contribute to it." From the overall EG,

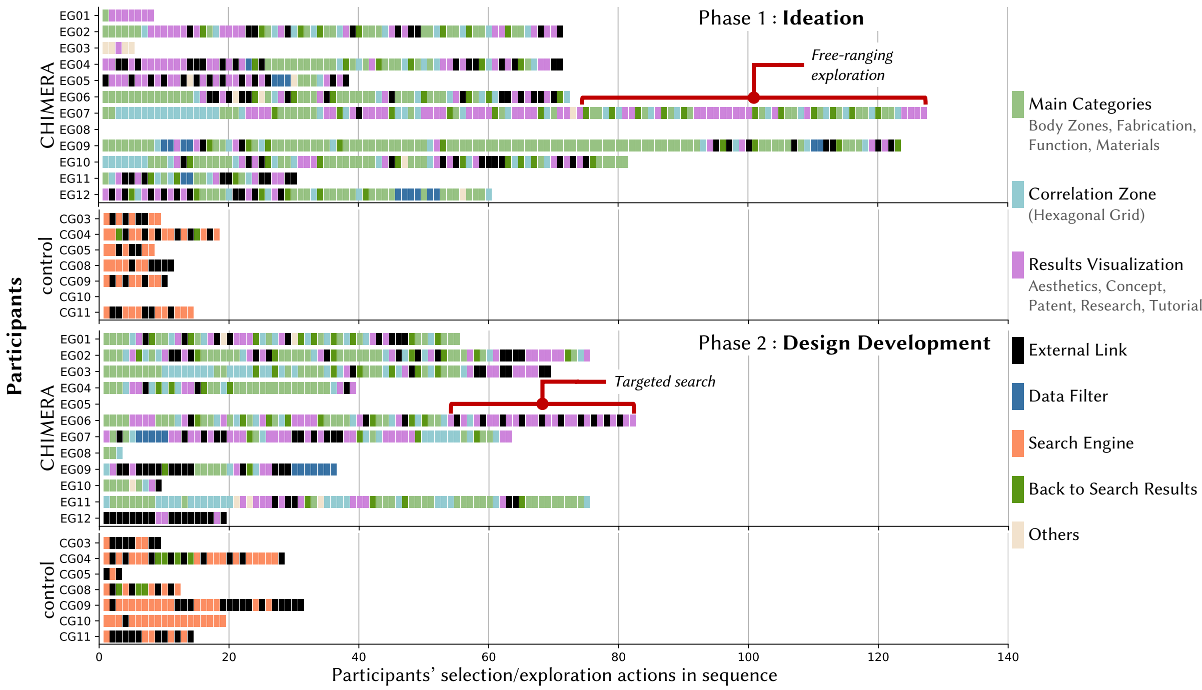

Fig. 6. Users' sequence of selection/exploration actions on the CHIMERA interface (EG) and on the baseline interface (CG) (a search engine) during Phase 1 (Ideation) and Phase 2 (Design Development). Clicks are coloured according to the broad categories in the interface. The horizontal axis represents the sequence of clicks during each phase. For instance, participant EG07 performed 127 selection/exploration actions during phase 1 while participant CG05 performed 3 selection/exploration actions during phase 2. Examples of free-ranging exploration and of targeted search are marked.

(3/12) participants commented that they would only share published information once the intentions of the website are clear.

Interface: EG participants reported how the CHIMERA Interface helped them discover wearables state-of-the-art—(12/12) participants recognise that they were able to access new information that helps them guide the design task and generate new concepts in their process. We noted two dominant styles of exploration during the design tasks: free-ranging through the interface and targeted search. When 'free-ranging,' participants tended to appropriate information found in the *Results Visualisation, Main Categories, and Correlation Zones* without necessarily accessing external links of information to integrate ideas into their designs. Participants used the word combinations from the elements in CHIMERA and the images provided as a resource of inspiration and ideation. In contrast, those using the 'targeted' search approach focused on finding methods and techniques to enrich the details of their concepts using knowledge extracted from CHIMERA's external links. Rather than beginning at the main correlation zone, we noticed that some EG participants began their search at the Main Categories or Correlation Zone. Despite beginning explorations within the CHIMERA workflow, this did not impact their exploration or interaction with the task. We noted this behaviour across both phases of the study (Fig. 6).

We further noted participants increase the exploration of multidisciplinary content during tasks. Fashion participants began with Materials selection and focused on textiles-related projects. They followed an exploration of Function and Fabrication Categories to discover sensing and actuating technologies, and composite fabrication techniques. HCI designers searched HCI topics and performed an intensive search on both fashion- and engineering-oriented work. Engineers defined a core function in an area of interest, (e.g. sensing), then connected this functionality to body zones. Overall, we observed that the EG found considerably more resources than those in the CG, often outside their domain of expertise (Fig. 6).

The versatility of CHIMERA is illustrated in the way participants used the tool to search for information (EG01, EG03). They rely on their background knowledge with minor support from the interface, such as element combinations, to sketch their designs and ideate. However, the exploration increased significantly when adding details and defining processes and practices for a specific design. We observed that these participants found CHIMERA beneficial in the development phase. In particular, when adding details and specifications for a design required additional knowledge. On the other hand, participant EG05's exploration and navigation of information peaked during the Ideation task. EG05 used the information collected during the ideation phase to refine and further develop the selected design in the development phase. As an exception, participant EG08 did not use CHIMERA during the evaluation. We attribute this behaviour to the confidence of the participant in their experience. However, the participant only listed functionalities that the design will have in the development phase without adding specifics or details. This behaviour was similar to the one encountered in the Control Group. The different patterns of search in Fig. 6 show how CHIMERA adapts to each user needs, independently of the design and goal in creating wearables. Some participants focus entirely on completing the tasks. Others were curious to see the information available in CHIMERA. We observe no linked patterns in searches afforded by background. For example, EG01 and EG05, both from a fashion background, demonstrate entirely different behaviour in both phases of the study. In the same way, EG07 and EG11, both from technology backgrounds, behave differently in each phase.

The resulting design concepts reflected the amount of information explored. During both tasks, search results and information accessed determined many of the details added to designs. Most participants in the EG (11/12) reported that they were inspired by CHIMERA to develop their concepts and detail designs. Participants noted that the visual navigation helped them extend their search. It sped up the exploration, ideation process, and diversity of ideas without changing their conceptualisation practices. EG11 explains: *"time was saved by just looking at the image before reading all the details of that device;"* and EG10: *"pictures may spark ideas, questions you were not necessarily searching for."*

Changes to CHIMERA: Participants described CHIMERA as an appealing, useful, powerful tool and look forward to *"using it in the wild"*. The data collected in surveys was thematically analysed using inductive codes. Given the range of challenges people encountered testing CHIMERA, we were able to draw conclusions and streamline the taxonomy, improve terminology clarity, and share user interface design and functionality. On the visual level, participants suggested: *"The buttons on the left didn't intuitively seem to be drop-down options (EG04)"*, *"I had some problems with the interface, mainly with how the hexagons are displayed and what's inside (EG03)"*, and *"I don't understand when does a hexagon become selectable or not (EG11)"*. Therefore, we added modifications such as a) regrouping the Categories, b) adding representative colours to the honeycomb structure and Categories that are activated during search interaction, c) provided a list of all current database elements, and d) increased the size of text inside the hexagons. On the functionality level, participants had issues with two main characteristics of CHIMERA: the application of filters and the need for a small tutorial about the functionality of CHIMERA. The filters were fixed, and a video tutorial was added to the CHIMERA intro page. Finally, the database is also starting to build backwards with earlier works that will show novices the evolution and progression of wearable technology through the years.

7.2 Expert Enquiry

We contacted 13 expert participants (9 self-identifying as female, 4 as male). All with wearables-related expertise in Fashion, HCI or technology, primary expertise in at least one field, and knowledgeable to expert proficiency in others. Participants were asked to grade their level of expertise (scale 1 to 10), and specify the number of years of experience in each field (i.e., fashion, HCI, or engineering). Experts tested the CHIMERA interface and answered a six-question evaluation survey that collected qualitative data. The first five questions analyse their background experience, and the final open-ended question invites feedback on our tool, taxonomy, database, and the overall experience of using CHIMERA. We then invited experts to engage in a free exploration of CHIMERA so that we might gain detailed insight into: challenges encountered; opportunities for change experienced while using the taxonomy; database gaps; and the interface.

7.2.1 Experts Evaluation Results:

Database: In this mid-stage study, experts described changes to CHIMERA. They voice their doubts on literature missing from the database *"between 1990 and 2010"* (E-02), *"missing arts-based, and early literature entries"*, and *"Anything to do with reusability, recyclability and circular design is very obviously missing and necessary in these times."*(E-03). For these participants, how these questions of representation are answered in the process of compiling the CHIMERA database is indicative of its credibility, and its usefulness as a tool for all multidisciplinary identities accessing wearables knowledge.

Interface: While getting a feel for using CHIMERA, experts formed opinions around improved interface functionality and intuitive navigation of categories, suggesting we *"use visual hierarchy (e.g., increasing the text size of the major categories) (E-05)."* Other important highlighted suggestions referred to the layout and visual feedback to make the navigation clear and straightforward. E-12 says, *"Since the silhoutte of the human is the 4th item that a person can list, it seems that it should be near the left side of the screen so that all "main attributes" are together and the honeycomb tiles will display the results. It is possible to shade in the tiles that are displaying results from the main attributes?*. While E-05 mentions, *"there should just be a button to select the whole body, and boxes to select the body zones."*. Deciding how to make the interface design frictionless involved not only finding the right, intuitive balance of our taxonomical elements on-screen, but attending to the details of the graphical user interface.

Changes to Taxonomy: The experts mention goals to streamline CHIMERA's categories. For example, Function: *"actuation, tactility/haptics and feeling - maybe under feedback"* (E-03). E-05 describes Material, *"I am a little confused about the categorisation of knits and woven. I initially thought they meant 'the process of knitting/weaving' but as I dove a bit deeper, I think some of those articles are listing designs that use woven materials—which should technically go under the material section."*. This excerpt highlights what it takes for a categorisation to be coherent, and which common language one expects to be represented. However, how to prepare the common ground for categorisation was of equal concern in this negotiation.

Some experts highlighted the importance of adding a filter for authors and resources names. We found the suggestion necessary because experienced researchers targeting specific content will benefit from this feature. The initial tested version provided a search bar linked to the taxonomy, example tags, and a side filter for the year, venue, and field. The addition of a filtering method generates an additional level for accessing information.Finally, we added new resources and venues to the data search system and the database to include work suggested from participants and experts to enhance content and encourage curiosity.

Experts found the taxonomy compelling and commented that: *"CHIMERA is a powerful tool for researchers, technologists, and fashionistas interested in wearables"* (E06). The use of term 'fashionista', over a term like 'influencer', discloses the nuances of this expert's background, as they use the phrasing and language familiar to

Table 3. Experts background and years of experience in Fashion (F), HCI (H), Technology (T), and Wearables (W).

	Expertise	(years)			Background and Expertise Description
	F	H	T	W	
E-01	10	5	5	5	(PhD) Sustainable methodologies for fashion and textiles, body perceptions, haptics and smart textiles life cycle, body awareness
E-02	2	20	20	10	(PhD) Industrial Design, digital crafts, virtual environments, collaborations with semi intelligent machines
E-03	0	15	30	20	(PhD) Media artist, immersive experiences, VR, XR, participatory performance, interactive art, soft circuits, fashion tech, DIY electronics
E-04	0	2	8	7	(PhD) Bio-inspired electronics, multi-material additive manufacturing, soft actuators, haptics, polymer design.
E-05	3	4	10	4	(PhD) Human factors, wearable technology, biomedical engineering, sensations in immersive environments, safe healthcare products, emotion manipulation through haptics
E-06	0	8	8	8	(PhD) Wearable biochemical sensors, sensors for healthcare, temporary tattoo and textile-based electro-chemical sensors, sweat-activated batteries
E-07	5	9	10	8	(PhD) Architect, rapid prototyping, design to production of textiles and Fashion, digital fabrication for installations, artistic creations, furniture
E-08	20	5	20	11	(PhD) Fashion and technology designer, sustainable computational craftmanship, knitwear and shoes fashion design, data-based personalisation of clothing
E-09	35	5	30	0	(PhD) Design and development of functional apparel, fashion manufacturing anthropometrics, body scanning, and 3D design.
E-10	9	14	14	14	(MA) Designer, artist, teacher, researcher, e-textiles, interaction design, physical computing, AI
E-11	25	1	6	6	(PhD) Fashion design, merchandising, sustainable apparel, circularity, product development, supply chain, adaptive apparel, quality management
E-12	10	10	15	9	(PhD) Sustainability, healthcare, product design, concept design, human machine interaction, decision-making
E-13	8	13	17	9	(PhD) Industrial design, teacher, soft wearables, smart devices, smart textiles, systems design

their domain of practice. Overall, the Exploratory Group and Expert participants reported being satisfied with the interface and interactive search functions - and suggested details for Interface/taxonomy/and database detailed in the next section.

7.3 Wearables Class

Our third study took place in an educational context at a university in Denmark. Eleven out of seventeen multidisciplinary MSc students in a wearables class decided to participate in the study. Students came from varied backgrounds and had no prior experience with wearables. The purpose of this study was to evaluate CHIMERA's efficacy in wearables design curricula, to support students during an 8-week module with an explicit deliverable—a functioning wearable prototype positioned within related work. Additionally, we sought feedback on CHIMERA at mid-to-late design stage, to record how novices interact with and discuss CHIMERA's attributes, refined and updated from previous studies. At the beginning of the course, all 17 students were provided with a link to CHIMERA. They were told it was an online database for wearables that they *may* find useful as they look for ideas and possibilities to design and position their wearable — no other instructions or guidance were given. The student participants (SP) were surveyed before and after the use of CHIMERA. An initial survey sought information on disciplinary backgrounds and experience with wearables. A closing survey invited the students to validate and provide their perspective on the taxonomy, database, and CHIMERA and its use in an educational context. The closing survey had twelve open-ended questions targeting required changes, desired features, and comparative perspective in relation to a conventional search process.

7.3.1 Pre-survey Analysis. We thematically analyzed the students' pre-survey and extracted their expectations, interests, and methodology for searching for wearables information. With their use of CHIMERA; the students expected to explore and learn methodologies, techniques, and materials that can allow them to interconnect and find body, mind, and technology relationships. They highlighted interests in identifying current technologies, moving from prototypes to market, creating seamless wearables that do not look like robots, and methodologies that can enhance acceptability and appreciation of wearable technologies. We were unable to define a specific pattern for searching information. Students report that their search methods are project-specific and determined by their understanding of the topic. They typically use videos, workshops, tutorials, and social media to explore information and follow trends. This information helped us to understand if their expectations were being met when using CHIMERA as a source of information as they conducted their wearables assignments.

7.3.2 Post-survey Analysis. We thematically analysed the post-surveys, and identified four repeated topics. The students (SP) commented that there were no barriers to access the information available (SP01, SP03, SP10), and the additional knowledge required will be in case one wants to implement or apply some of the resources offered in CHIMERA (SP08, SP09). The students highlighted that there is no particular knowledge required to use CHIMERA because it is self-explanatory. Users might only need an idea of their end goal (SP08, SP11). When we asked about the amount of information they found in CHIMERA, the SP said a conventional search could provide more results. However, "*the amount of information I might find using my methods can become overwhelming if I still have a broad spectrum of possibilities to cover*" (SP01, SP03, SP07, SP09). On the other hand, with the wearables-focused database, CHIMERA became a great source of inspiration, ideation, and research for their concepts, prototypes and projects during the class module (SP01, SP02, SP04, SP05). SP11 says, *"it gave me a feeling of excitement when I saw all the pictures, elements, concepts ...It interests me to explore."*. This insight reveals the particular relationship between coherent content and design inspiration, which drives the goal participants work towards. SP06 described this process simply, *"It helped us to be more inspired, we gathered more information that could help lead us to do more explorations."* The fact that the surveys and the usability of the tool took place in an uncontrolled educational setting with novices, highlights the potential that CHIMERA brings to the community. CHIMERA impact is visible in three levels; it 1) reduces the knowledge and background barrier to access and share information, 2) increases awareness of current practices, and 3) inspires and motivates developers.

8 DISCUSSION

8.1 Knowledge Awareness

Our study suggests that CHIMERA enhances exchange and improves literacy between fragmented knowledge fields. The wearables field is dynamic and heterogeneous. It is not feasible for a single designer's knowledge to span all domain-relevant resources. Common shared terms differ in meaning across fields, which complicates accessibility of information. CHIMERA brings diverse information together using the language of an accessible

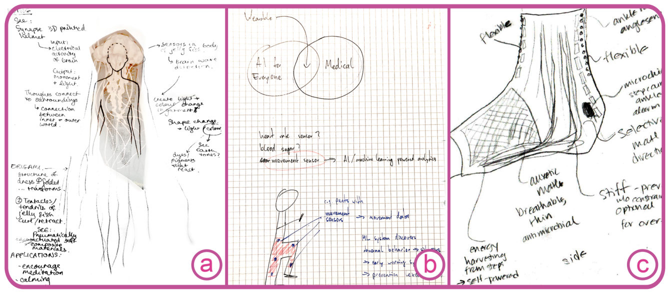

Fig. 7. Design logs selected from participants with different backgrounds during the Phase 2 Design Task to illustrate the common attribute of theorising practice through sketching across all three backgrounds. The Logs correspond to participants working in a) Fashion; b) HCI; c) Engineering

cross-disciplinary Taxonomy. In reflecting on the taxonomy, EG12 notes: *"I would not have thought of the categories in the first place. So, now, I would be able to think from different perspectives"*. The wearables taxonomy, made operational through the CHIMERA interface, opens the door to multi-perspective navigation and thus—we argue—to diffractive engagement with cross-disciplinary resources. Such engagement democratises access to heterogeneous data. Centralising information allows users to stay informed in state-of-the-art knowledge across disciplinary divides.

Across our studies, it became evident how a lack of multidisciplinary vocabulary impacted the quality of people's searches. CHIMERA's search process enables users to overstep knowledge barriers to access information not traditionally associated with their usual practices. Accessible information unleashes a series of benefits for users. It affords procuring knowledge, with awareness of new principles and practices from multidisciplinary points of view, which boosts curiosity and promotes innovation.

8.2 Common Vocabulary

Web search engines are useful to gather ideas about a topic. Our observations of the Control Group (CG) reveal that conventional methods of search—using topic-related words coupled with expectations of useful results—slows down the conceptualisation process and generates distraction. To find inspiration, CG participants spent long periods reading and filtering search results in forums, personal websites, social media or company platforms. In contrast, CHIMERA enabled our study participants to move quickly through filtered information (Fig. 6) and eliminate the need to transform thinking processes into keywords to initiate a search, a limitation of conventional search engines. As Participant EG06 notes, *"finding that keyword is often the biggest challenge in finding the right information"*. CHIMERA addresses this limitation by using the taxonomy of higher-order Categories and Elements that represent terms with common base points across multidisciplinary perspectives—and by using visuals to present search results. The taxonomy thus helps designers to effectively transform ideas into searches, gain fast and easy access to the repository, and navigate in an organised way the wearable state of the art.

8.3 Boost of Creativity and Innovation

The CHIMERA interface and taxonomy open up new knowledge spaces for users. Our participants state that CHIMERA *"helps trigger conceptualisation"*, particularly for *"projects where you are not quite sure where to start looking"*, when one *"needs to find some inspiration"*, or to *"forge links between multidisciplinary design and tech experts"*. Independent from background knowledge, designers search for information to expand their vision and capabilities. EG08 reported *"I would be able to think from different perspectives"*. We observed depth and detail in participant design logs, which verify novel perspectives in their design work. CHIMERA facilitates access to resources that an experienced designer may find challenging to uncover in a single search. Participants in EG were able to speed up their search process by accessing customised filtered information. This outcome was reflected in the volume and details expressed in design logs. While the differences across disciplines may be challenging to work through in a collaboration, we identified common attributes. For example, theorising wearables practice through the design ideation technique of sketching, shown in design logs representative of each background field (Fig. 7).

We could see that opening access to work across disciplines can speed up the creation of new technologies, interactions, and research [57], providing a different perspective and vision of the technologies used in the design logs. The taxonomy that underlies CHIMERA, enables designers from distinct disciplines to focus on search content, rather than search methodology. CHIMERA serves as a tool to access opportune state-of-the-art knowledge, and accelerate design actions towards deliverables. However, it is not intended to marshal a designer's actions, nor automate design solutions.

Notably, when knowledgeable and expert participants searched for a specific author, result, or their own work, this complicated their use of CHIMERA. Therefore, we implemented a search bar feature and filtering by author to accommodate the needs of a larger spectrum of users. Notably, when participants explored without a specific result in mind, their interaction experience was comparatively frictionless.

8.4 Visual Navigation

Visual cues that afford quick analysis during a search were valued and appreciated by all experts and practitioners in our study. Designers are generally visual [44], fashion participants visually filter sources, using image navigation to steer an overall concept aesthetic and style. One participant reported they would like *"the internet to be able to understand the picture I have in my mind and give me all the information without entering the right sequence of words"*. Another stated that images give rise to serendipitous *"follow the trail"* mental content processing, marking common patterns and themes to validate initial design ideas. Visual concept navigation allowed CHIMERA to adapt to many different search and user types while providing access to multidisciplinary information with different scopes. CHIMERA manages different parts of the workflow process. Some people used the Search criteria selection dynamically to adjust and hone the Correlation Zone hexagrams of the main screen to access Results Visualisation. Other participants were inspired to explore and scroll content for project discovery in the Results Visualisation. Overall, a curated display of visual information was considered an asset that reduced the number of off-topic images to scan, sort, discard while scrolling knowledge sources mentally—reducing the participants' mental load during the search, and generating desired process-specific information.

9 LIMITATIONS AND FUTURE WORK

9.1 Long-term Potential

CHIMERA is a first step towards empowering a multidisciplinary group of researchers, developers and educators to access and expand wearables state of the art. It is a tool to strengthen connections between disciplinary silos, and its relevance as a multidisciplinary design ideation support is clearly shown in each of our studies.

Future studies will explore the impact of the interface as a creative, learning space that enhances access to existing knowledge across diverse multidisciplinary perspectives, from novice to expert. To these ends, we are expanding the integration of CHIMERA into wearables design curricula, classes and workshops, and promoting its existence and purpose to colleagues, peers, and other experts. CHIMERA prepares a starting point to ground the common language necessary to access multidisciplinary information. The studies do provide however a deeper understanding of how novice to expert multidisciplinary users manage the CHIMERA and our taxonomy to develop wearables designs. We anticipate the value of a) expanding our studies to specifically target the collaboration of multidisciplinary identities within group design, and b) expert evaluations of novice design tasks using CHIMERA. Based on responses to date, we expect its use to contribute to thriving digital spaces. Since COVID-19, we have seen virtual gallery platforms emerge that centre visual navigation. These curated virtual spaces yield conceptual possibilities for design projects, interactions, and media streaming in remote connections when people can not physically see each other [29]. Further, from what we understand has happened with the HFI Literature App and Haptipedia [6, 50], our taxonomy and database will both develop and be developed by the community that gathers around CHIMERA. At present, CHIMERA is not well resourced to negotiate fashion and technology manufacturing systems. Attention to production and supply chain difficulties remain a principal barrier to the successful implementation of wearables in society. In our future study, we plan to develop a framework into a design method, which will expand CHIMERA and complement and address this limitation.

9.2 Collaboratively Growing the Database

CHIMERA is a sharing platform, and its database must continually expand if it is to represent state of the art and be a useful community resource. Although we anticipate this expansion may challenge the taxonomy, it is essential to maintain relevance. Community collaboration and peer-review will ensure representation of diverse perspectives. At present, HCI, fashion, and engineering fields populate the database; we expect to expand wearables resources endorsed by fields such as the arts, theatre, dance, and performance. Our studies confirm that people desire intuitive ways to connect and collaborate with authors, share knowledge, and offer community design patterns and protocols.

9.3 Additional Features

We anticipate full access to CHIMERA will enrich communities of developers, such as WEAR Sustain , a Europe-wide wearable technology, smart and electronic textiles network suggested by one of our experts. We are now creating an automated data collection tool to collect relevant research and patents from the google scholar database, and tutorials, aesthetics and concepts from well-known sites such as Instructables and Arduino. CHIMERA's data collection tool will continually expand the database, positively impacting knowledge awareness, accessibility and knowledge transfer. Based on our findings, we will expand CHIMERA to allow individual users to create content profiles and group workspaces for collaboration and future networking across the wearables community.

10 CONCLUSION

Our paper presents a three-fold contribution to wearables development. 1) a Wearables Taxonomy; 2) a database of related research, tutorials, aesthetic approaches, concepts and patents; and 3) CHIMERA, an online interface that provides visual, taxonomic connections to the growing database. To determine the effectiveness of CHIMERA and the taxonomy, we conducted a multidisciplinary design study, experts enquiry, and validation in the wild with students of a wearable class. Our evaluation of CHIMERA in use mapped participant approaches across disciplinary backgrounds and varying levels of professional expertise. Personal design ideation preferences can be complicated, notably in a multidisciplinary field such as wearables. Our study reveals a hybrid design territory where digital interfaces can bridge multidisciplinary communities; expand individual capabilities; enrich design experiences and enable developers to go beyond their working knowledge background. Despite its exploratory nature, our study confirms that CHIMERA and the taxonomy fulfil these needs and offer valuable insights into targeted search (Fig. 6) of multi-faceted wearables resources and diffractive reading of the results. Our contributions combined globalise knowledge accessibility, promote the development space of wearables, and encourage mutual exchange among developers. We hope that CHIMERA will empower emerging and established designers, educators, researchers, and practitioners from across the wearables landscape.

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