All things bio: a conceptual domain-based approach to mapping research and practice within the landscape of biologically informed disciplines

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The research presented in this paper tackles the problem of terminological disharmony within biologically informed disciplines (BID). Lexical semantic theories and methods are applied to corpus-based investigations to assess the scope of BID terminology. The results are analysed using statistical and qualitative methods and mapped against known academic domains. The resulting map is evaluated via the analysis and consequent positioning of biologically informed textile research. The findings suggest that the experimental framework embodies an alternative approach to mapping practice within BID landscape that overrides the need for broad, generic terms. Instead presents the work within an established network of theories and concepts with transparent interdisciplinary connections.

Keywords: biomimetic; biomimicry; bionic; biodesign; bioart; textiles; practice based research

Introduction

Biodesign, biofabrication, biomimetics, bioinspiration, etc reflect emerging concepts to design and innovation that promise innovative and alternative paradigms for design, building and manufacture. However, the prefix bio- and terminology pertaining to interdisciplinary activity centred around biology and its numerous sub disciplines are difficult to navigate, especially by researchers from non-scientific sectors. Iouguina (2013) proposed *biologically informed disciplines* (BID) as an umbrella term for the sector to consolidate the range of bio-related activities. Wahl (2006) identified two distinct areas of discourse within the BID landscape, one focused on ecological issues and the other technological innovation (Wahl, 2006). Although both groups share the terms biomimetics and biomimicry which are identical from a lexical perspective, the words carry significantly different meanings.

The diverse range of meanings for a small number of terms (polysemy) is a significant factor that contributes to terminological disharmony; a systemic issue within scholastic BID discourse as reported by several scholars (Lepora, Verschure and Prescott, 2013; Vincent, 2014; Vincent, 1997; Vincent et al., 2006; Kapsali, 2016; Wahl, 2006; Iouguina, 2013). This phenomenon was studied by Iouguina, Dawson, Hallgrimsson and Smart (2014) using a combination of lexical semantic theory and ethnographic methods. The ethnographic part of the study focused on pinpointing the different semantic values placed upon the morpheme [-mimetic] by key actors from both the ecological and technological sides of the community. The findings confirmed the dichotomy reported by Wahl (2006). This study builds upon previous work (Wahl, 2006; Iouguina, 2013; Iouguina et al., 2014) to map the range of discourse at the intersections of biology with science, technology, art, and design using linguistic theories and methods.

BID terms have emerged organically in response to dynamic activity in the area, by the very researchers developing new knowledge (J. M. Harkness, 2004; Vincent, Julian FV, 2001; Pecman, 2014). These terms function as signposts to disseminate findings but also to establish the researcher's own position within the primarily scientific communities operating in this space. However, this approach has grown to include wider range of academic disciplines, which introduces new layers of complexity to terminology and it's use.

Theoretical context

Terminology, a sub-category of lexicology (Azimjanovna, 2020) is a new area of study within linguistics. *Lexicology* focuses on the study of the nature and function of words as symbols and their relation to other words within the lexicon. Faber (2009) introduces a cognitive dimension, as such, regards *terms* as linguistic units which convey

conceptual meaning within the framework of specialised knowledge texts to facilitate specialized communication, translation and knowledge transfer between text users belonging to different language communities. From a social perspective, terminology is also used to enable researchers to carve out a space for their field within society and to establish themselves in contact and competitions with others within their group (Gunnarsson, 2011).

The rapid growth in scientific and technological knowledge, observed during the last century (Caso, 1980; Grene and Depew, 2004), has triggered a surge in the formation of novel terms to express new concepts, methods, materials, and tools. The traditional method of coining scientific terms draws on Greek and Latin roots, however this is no-longer the case (Caso,1980). The formation of contemporary scientific terms is informed by internal and external factors, often in a chaotic and spontaneous manor (Azimjanovna, 2020) by scientists, who are not necessarily trained in the classics or linguistic theory and 'work in fields of science that do not have a strong tradition of resorting to ancient languages' (Caso, 1980).

From a morphological (or lexical) perspective, terms are composed of smaller lexical elements (morphemes) and phonemes (basic sound units). Lexical semantics is concerned with the meaning of lexical units, specifically on the identification and explanation of word meaning via diachronic (how the meaning of words change over time) or synchronic (current) perspectives (Hanks, 2006; Cruse et al., 2002; Geeraerts, 2010).

Faber (2009) notes that the theoretical proposals in the field of terminology have been mostly practice-based, arising from the elaboration of glossaries, specialized dictionaries, terminological and translation resources (Faber, 2009) by scholars in

applied linguistics such as translation (Faber Benítez, 2009; Azimjanovna, 2020; Pecman, 2014).

New lexical units are created via *word formation* (WF); a specialised branch of language science which studies the patterns with which a language forms novel words (Marchand, 1969). WF is limited to composites which are analysable both formally and semantically. Composites rest on the relationship between morphemes through which they are motivated. A morpheme is the smallest unit of language that has its own meaning, either a word or a part of a word: *worker* contains two morphemes: *work* and *-er*[1]. A comprehensive range of WF mechanisms (including semantic, morphophonemic, and functional change in addition to composition, borrowing and neologising) specifically used in the creation of new scientific terminology was identified via Caso's (1980) study of a bespoke corpus populated by scientific journal articles.

Lexical units carry meaning(s) (concepts) as well as a syntactic valence (Faber, 2009). Core to the study of word meaning and its creation is the distinction between mechanisms of onomasiology (naming) and semasiology (meaning); lexicogenesis is the practice of making new word forms and meanings; regardless of whether the concept described is new or existing, it is expressed by a new or alternative lexical item (Geeraerts, 2010). Caso's (1980) view is that that lexicogenesis of scientific terms has had significant impact on the lexicon at large.

Faber (2009) describes systems formed of concepts relating to specific areas of human experience that provide the necessary contextual knowledge for our understanding of the world around us. This knowledge is referred to as *domains* (Langacker, 1987) or *frames* (Fillmore, 2006). A domain may be defined as any

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[1] https://dictionary.cambridge.org/dictionary/english/morpheme

knowledge structure that is of relevance to the characterization of a certain meaning (Paradis, 2012); it can sometimes refer to the knowledge area itself, and other times, to the categories of concepts within the specialized field (Faber, 2009). On this basis, the mapping of relevant morphemes against established domains can provide insight into the configuration of the wider BID landscape as well as the internal structure of individual domains.

This study is concerned with terminology pertaining to BID a particular area of research that began in the 1920's with a handful of scientists from biology, physics and chemistry working collaboratively to explain phenomena in biology and model findings using technology. The first systematic, multi-disciplinary study linking biology and physics can be traced back to Otto Schmitt (1913-1998) and the collaboration with his older brother Francis. Schmitt was an extraordinary polymath who drew on biophysical and biochemical methods to the study of the molecular organization of cells and tissues with reference to nerve fibres and applied findings to the invention of several electronic components still used today (Harkness, 2004).

It wasn't until the 1960's that momentum increased in this space; triggered by the Bionics Symposium events that took place between 1960 and 1963 and were funded by the US Air Force. Scientists from a wide range of disciplines including medicine, electrical engineering and computing participated in these events. Although *bionics* (Steel, 1960) was the term proposed by the symposium organisers, Schmitt proposed alternative terms such as *biological engineering* (Schmitt, 1954), and *biomimetics* (Schmitt, 1963) to define the novel concepts emerging from the discourse.

A significant surge in BID was reported by Leopara (2013) in the early 2000's specifically within the context of engineering and robotics, however the concept has

spread widely into other academic domains. As such, the original terms have been recycled, remodelled, and adapted to meet the needs of new actors in this space.

Methodology

Fabre (2009) advises that the approach to linguistic analysis of terminology should be lexically centred, usage based and focused on meaning and conceptual representation. As such, BID terminology is studied via formal (lexical) and semantic perspectives. Digital corpuses are used to access historic and synchronic data. Queries are conducted via web-based tools aligned to each specific corpus. The results are displayed using standard frameworks within corpus-linguistics such as KWIC (key word in context), *frequency*[2] and *concordance*[3] *lists*.

The objective of the initial corpus search is to identify the range of unique BID morphemes, this is achieved via the analysis of frequency and concordance displays of search results. Semantic analysis is conducted by grouping individual morphemes into conceptual clusters (domains). Mapping morphemes onto a well-established framework of academic domains provides a credible structure on which to position new BID activity to mitigate the ad-hoc way in which terms have emerged.

Further corpus queries are used to hone in on specific terms to clarify semantic value by analysing and comparing *collocate*[4], KWIC and concordance views of the

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[2] A generated list of words grouped by frequency of occurrence within a specific corpus.

[3] A generated list of instances in which a particular word occurs in a digital corpus, typically each expression is presented within the context in which it occurs.

[4] a *collocation* is a series of words or terms that co-occur more often than would be expected by chance.

data. This is especially useful to determine semantic value of newer terms that are not yet established within the wider lexicon and thus represented in a dictionary such as *bioart* and *biodesign*.

The results of the corpus studies are consolidated onto the BID map (BID individual morphemes plotted against academic domains). The relevance of the map as a framework to position individual practice within the context of disciplines which inform the research, is tested via plotting five case studies on the BID map following a top-line analysis of interdisciplinarity. The case studies selected share the topic of textile innovation to provide a focus for this experiment.

Diachronic study

The origin of the terms biomimetic(s) and bionic is widely reported (Harkness, 2004; Vincent et al., 2006; Kapsali, 2016), this specific action seeks evidence of BID morphemes via the analysis of academic texts from 1960-1993. The British National Corpus (BNC) was selected for this study. The BNC is a collection of samples of written and spoken language from a wide range of sources, such as regional and national newspapers, specialist journals, academic books, popular fiction, school, and university essays. The BNC contains about 100 million words and was designed to represent a wide cross-section of British English, both spoken and written, from the late twentieth century.

Unique morphemes are identified via statistical and morphological analysis and compared chronologically across the periods 1960-74, 1975-84, 1985-93[5] to provide a

[5] As per the chronological structure of the BNC.

view of the scope of BID terminology and its impact on the lexicon. A comparative analysis of the presence and/or appearance of novel BID morphemes, for each period, is performed between scientific and arts/ humanities genres of academic text for evidence of terminological transfer between domains.

Synchronic study

A current view of the range of BID terminology is studied via the analysis of synchronic, digital, web-based corpuses. The one hundred most common BID morphemes are identified using the approach described previously. The morphemes are grouped broadly into conceptual domains, further study of each grouping is conducted to reveal the underlying structure of each domain.

BID domains are plotted against the established framework of academic disciplines to reveal a map of current activity and most importantly, interdisciplinary connections. The suitability of the map as an alternative approach to contextualising activity is tested via the analysis of design-led BID research on the topic of textiles.

Findings

This section presents the results from the historic (1960s-1993) and current (2020) study of BID terminology. The results of the experiments are limited by the nature of the corpuses, i.e. single language, selective texts. As such, outcomes are regarded as indicative rather than a definitive account of events and trends.

Diachronic study

An individual word query was performed for the expression [bio*]. The expression was designed using the Simple Query Syntax (Hoffmann et al., 2008) where the symbol <*> functions as a wildcard denoting zero or more characters. For the purposes of this study,

the wildcard was positioned after the prefix bio- to request a search for word formations that begin with bio- and are followed by zero or more characters to return the widest possible range of BID terms.

Additional search restrictions were set to focus on written texts and specific chronological periods; 1960-1974, 1975-1984, 1985-1993. The resulting concordances revealed the total number of *tokens* or instances of word formations meeting the search criteria and *unique words* present within the range of tokens. A chronological view of total tokens and unique words is presented in table 1. The BNCweb unique formation function considers derivatives of the same root such as *biologist* and *biologists* as two individual word forms. As such, the number of unique forms as presented in table 1 is regarded as indicative, however the increase in total tokens suggest significant growth in terminological use from the mid 1980's until 1993 (inclusive) while the increase in unique words suggests impact on lexicon size.

The most common unique words per period were identified using the BNCweb frequency function. These were further examined for common morphemes and merged; for example, the number of individual occurrences of the morpheme biolog- (i.e. biologists, biological with biologically) were combined. The results are presented in figure 1. Morphemes concerning the term biology and its derivatives are consistent across all three periods. The morpheme biograph* (morpheme pertaining to the description of an individual's life) and all its derivatives were removed as they are not within the scope of the study.

Word clouds are electronic images comprised of words from an electronic text or a series of texts. The size of each word within the image is scaled according to the frequency in which it occurs within the electronic text. *Word cloud generators* are digital tools that create images from digital text input by the user. Some generators

allow the user to specify the weight of each word using a .cvs file rather than inputting a body of text. A word cloud image was created for each period to include the entire range of unique word formations from the period. Raw data from the results of the corpus searches were used. Terms omitted from the previous study are included (such as derivatives of biograph-) for context. The image for period 1985-93 omits 35 of the least frequent words due to image size restrictions. This is considered acceptable as the aim of this experiment is to visualise the increase in new bio- related terms. The resulting digital images from period 1960-74, 1975-84, 1985-93 are presented in figures 2a, b, and c, respectively.

Terminology transfer

The query [bio*] was repeated with additional restrictions designed to isolate use of the term within specific genres. Two genres were selected for comparison 1. Natural sciences and engineering (Science) 2. Arts and Humanities (Arts). Figure 3 compares the number of tokens and unique word forms between the art and science genres chronologically. Derivatives of the morpheme biograph- feature heavily in the Arts genre, as this is not within the scope of this study, the data was removed. Relevant tokens first appear in the period 1984-93 within the Arts and Humanities, this suggests the emergence of BID concepts as a novel topic of discourse within this domain.

The list of most frequently occurring terms per genre was analysed for common morphemes and combined using the approach described previously. The most frequent morphemes across the two genres per period are presented in figure 3. Morphemes from the Arts during periods 1960-84 do not feature in the graph because no relevant tokens appear during this period (i.e. morphemes that are not biograph-), however significant activity is noted in the following decade. Specifically, morphological derivatives of bio- directly related to the subject of biology feature prominently.

A further query for the expression [biolog*] restricted to written text, Arts and Humanities genre during the period 1985-93 produced a concordance (appendix 1). This format enables the review of each token within the sentence it appears, as such providing an idea of the context and use of each term. Analysis of the concordance reveals discourse that draws together biological concepts with social and philosophical disciplines. The BNCweb distribution function presents meta-data in terms of the text type, authorship, and audience base; the results from the [biolog*] query (appendix 2) reveal the textual domain of Belief and Thought was the primary context for relevant tokens, followed by Arts and Social Science.

Synchronic study

Wiki Corpus and iWeb were selected for synchronic study; the Wiki Corpus contains the full text of Wikipedia comprising of about 1.9 billion words and 4.4 million web pages. iWeb consists of approximately 95,000 websites, selected primarily by scale (the size of each website include in the corpus comprises of an average of 240 web pages and 145,000 words). The limitation of both corpuses is that the content is intended for communication purposes and is either crowdsourced (Wikipedia) or curated by individuals or organisations(websites), as such use of language and credibility of contents are problematic. Nonetheless, Wikipedia and the wider web are democratic and dynamic platforms used by many to share knowledge including those working within BID. For the purposes of this study, the Wiki and iWeb Corpus present ideal data sources due to their considerable size and breadth.

The same structure for the query expression [bio*] was applied as per the diachronic study. The resulting total number of tokens and unique words returned, are presented in table 2. The same caveat regarding the identification of ‘unique’ words by the algorithm performing the analysis as per previous study, applies. As such, the

number of unique forms presented in table 2 should be regarded as an approximation of size rather than definitive value.

The 100 most frequent word forms from both corpuses were analysed firstly to identify common roots; terms referring to biographical concepts were omitted such as biopic (neologism referring to a biographical film), also terms relating to the title or characters of games were omitted from the data such as BIOWARE. Although biolog- was the most common morpheme, it is omitted from the data presented in figure 4 because the total number of tokens was more than seven times the total of the second most common morpheme biochem- and as such dwarfed the data of the other terms. Figure 4 shows the resulting most frequent bio- terms after biology-, it is worth noting that this is a snapshot of word frequency specific to the date and time accessed, as such, this list is expected to change and vary with time.

BID conceptual domains

Bio- morphemes denoting conceptual domains are mapped against established framework of academic disciplines (table 3). This enables the distinction of terms coined to express new conceptual domains from the combination of two or more academic disciplines or domains and/or sub domains, the primary being biology. The mechanism of WF, in this case, is composition. It is possible to deduct from table 3 the following word formation pattern: [bio] + [domain 1], e.g. biophysics; [bio] + [sub-domain1], e.g. biomaterials; [bio] + [domain1] + [domain2], e.g. biogeochemistry.

It is worth noting that the analysis of the most common BID terms reveals significant impact on the life and applied science lexicon. However, specific terms relating to the intersection with the Arts and Humanities, do not feature, such as *bioart* and *biodesign* apart from *bioethics* which resides within the discipline of philosophy.

Another observation is that *bionic(s)* is more commonly present within the corpuses than *biomimetic(s)* and *biomimicry*. A corpus query for the terms [biomimetic] and [biomimicry] via the wiki corpus returned concordances that show the former is used as a general descriptor of process within technology focused texts, while the latter is used within the context of sustainability and circular economy (see appendix 3,4). This supports the findings of Wahl (2006) and Iouguina et al (2014).

Table 3 also provides some insight into domain structure. Grouping of remaining BID terms revealed further dimensions such as material/concept, technique/device, quality/property (fig. 5).

Interestingly, within this framework the terms bionic, biomimetic(s)and biomimicry could be plotted against the property/quality but do not contribute any additional insight or information of value. Bionic could constitute a BID sub domain as in some cases, it reflects the cross disciplinary domain of biology and electronics. Nevertheless, bio-mimetic(s) and -mimicry are too expansive to constitute a domain of their own.

Discussion

Benyus (1997), proposes a framework for biomimicry whereby nature is regarded as a *model* for technological innovation that solves human problems; a *measure* to set ecological standards and as a *mentor*, a new way of looking and valuing the natural world (Benyus, 2002). This view has emerged from the intersection of Systems Theory and Ecology, the former a sub-discipline of Sociology and the later a sub-discipline of biology. As such, biomimetics, by default represents the opposite view, the technological approach. This can appear (when compared to a wider, systems view) as narrowly focused on specific technological innovation. This approach also provides a lens by which to divide the BID landscape. Incongruously, both terms are

morphologically identical; they share bio- prefix from Ancient Greek root bios meaning life and root -mimesis meaning to imitate (see table 4).

Contrariwise, Vincent (2001) takes an inclusive approach he regards these terms 'to mean the same thing'. From a historic perspective the term biomimetic has not been without controversy. Coined by Otto Schmitt (1913-1998) a polymath who excelled in the disciplines of physics, zoology and mathematics, Schmitt originally used the term biological engineering in 1954 to nominate the concept of '*intentional theft of engineering designs from biological organisms for incorporation in engineering systems.*' Jack Steel used term bionics to describe the same concept in 1960 within the context of a Bionic symposium he co-organized for the US Air force. Schmitt, attended the event and was playfully critical of the connotations associated with the term bionic and the logo used to visually represent the concept (Kapsali, 2016). At a subsequent bionic symposium in 1963, Schmitt used the term biomimetic for the first time in public during his keynote:

> 'Let us consider what bionics has come to mean operationally and what it or some word like it (I prefer biomimetics) ought to mean in order to make good use of the technical skills of scientists specializing, or rather, I should say, despecialising into this area of research. Presumably, our common interest is in examining biological phenomenology in the hope of gaining insight and inspiration for developing physical or composite bio-physical systems in the image of life.' (Schmitt, 1963)

Harkness (2004), describes Schmitt's approach to the promotion of new concepts as purposefully unaggressive. Schmitt did not seek to establish the term biomimicry above bionic or any other related word-form (i.e. via the implementation of a dissemination / communication strategy such as publication in high quality journals). A sentiment echoed by Vincent (2001) who has been known to deflect attention from discourse around the semantics of terms and onto the purpose and potential of the work.

Biomimetics was originally created to express the application of knowledge specifically from the intersection of biology, chemistry and physics, all domains within the natural sciences. The notion has since spread across all academic disciplines, as such is underpinned by a wide host of theories and concepts. The lack of a single unifying theory and methodology in this space is often reported in the discourse (Bar-Cohen, 2011; Iouguina, Dawson, Hallgrimsson, & Smart, 2014; Mazzoleni, 2013; Myers, 2012). Iouguina (2013) observed that the overarching BID field has emerged from interdisciplinary practice-based research that is clumsily positioned among misinformed and ambiguous terminologies.

Furthermore, the increase art/design research and practice intersecting BIDs coupled with the divisive use of terms, highlights the need for tangible and specific framework to map new ideas and practices that clearly reflect multi-disciplinary contributions to new knowledge. This approach would also facilitate the positioning of work in a way that mitigates the impact of cultural differences between the academic domains such as use of language and approaches to practice and knowledge creation.

Bio- art and design

This section reviews the emerging spaces of bioart and biodesign within the context of the proposed framework (fig 5). It is noteworthy that no verified dictionary definitions are offered for the terms via established web resources. The semantic value of [bioart] and [biodesign] was investigated using the Wiki Corpus with a focus on collocate (words found either side of the search term) and KWIC (Keyword in Context) display of data.

The [biodesign] collocate query sought out words that immediately follow the term. The query returned the word ‘institute’ in the majority of instances. This was also evident in the KWIC view of the data (appendix 5). The primary purpose of ‘Biodesign

institutes,' as suggested from the data is health and wellbeing. However, within the design research communities, biodesign signifies 'the incorporation of living organisms as essential components, enhancing the function of the finished work. It goes beyond mimicry to integration, dissolving boundaries and synthesising new hybrid typologies' (Myers, 2012).

However, a [bioart] query revealed the words 'art,' 'project' and 'practice' as the most popular collocates that follow the term. The KWIC (key words in context) display returned words such as practitioners, project, practice, and cell culture. Bioart is regarded as a specialist form of art practice where humans work with live tissue, bacteria, living organisms, and life processes in general. This type of practice involves collaboration with the life sciences and/or medical disciplines. Techniques from various aspects of biotechnology are applied to the creation of artworks, these include tissue engineering, cloning and genetic engineering.

The corpus study suggests that bioart and biodesign have similar semantic values, in that techniques from biotechnology are applied to the creation of practice, be it for innovation, speculation (design) or provocation, social commentary, entertainment etc (art). It is possible to positions biodesign and bioart within the BID landscape (fig. 6). Further analysis of sepcific design case studies seek to interrogate the meaning and structure of biodesign as a domain and consequently, evaluate the proposed BID framework as a tool for analysing and mapping individual research practice.

BID design case studies

Five case studies were selected on the basis that the research was practice based, biologically informed, and led by designers working with textiles:

- Tissue Engineered Textiles (TET), Congdon (2020) is a textile practitioner exploring how traditional textile craft techniques can be utilised to create novel approaches in the field of tissue engineering.
- Programmable Knitting (PK), Scott (2015) is a knit specialist exploring how to design programmable knitted textiles using hygroscopic mechanisms from botany; development of environmentally responsive textile systems composed of natural and sustainable materials. Smart textiles made from simple materials.
- Biocouture (BC), Suzanne Lee[6] is a fashion designer exploring the appropriation of kombucha fermentation techniques for the production of bacterial cellulose material and it's processing (shaping, colour, and texture) into textiles and clothing archetypes.
- Mycelium Textiles (MT), Maurizio Montalti[7] is a design consultant focusing on the study and analysis of the mechanisms underlying structural and decorative properties of mycelium as well as their improvement via factors such environmental growth conditions and genetic qualities of different strains of mycelia. Montalti's vision is to develop alternatives to traditional oil-based plastics, in the context of this project, alternative synthetic leathers.
- Hygroscopic Textiles (HT), Kapsali (2009) is a textile designer applied design principles of hygroscopic shape change observed in seedpods design of fibres and textiles with responsive shape-change properties.

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[6] https://ideas.ted.com/tag/biocouture/

[7] https://www.corpuscoli.com/projects/the-growing-lab/

The BID conceptual domain structure is used as a framework to express each individual case in terms of established domains, material/concept, technique/device, quality/property. Descriptive and generic terms are omitted from the analysis. The results are presented in table 5.

Each case is plotted onto the BID domain map (fig 7), domains not relevant to the study were removed. The resulting map reveals a more complex view of activity within the fashion and textile design sector. Interestingly, design practice does not exclusively interface with biotechnology, the review of a small range of case studies reveals a much more complex landscape. It is also noteworthy that sustainability influences the research via the biosystems domain; specifically, biodegradability and notions of circular design such as recycling, reuse, and waste as resource. Although not all cases reviewed, featured sustainability as a driver, this does not mean that the work is void of environmental concerns.

Conclusion

This study presents a novel approach to mapping the area of BID based on linguistic analysis of terminology pertaining to the field. Corpus linguistics aided the historical study of bio- morphemes and revealed an increase of relevant terms during 1985-93. Furthermore, evidence of BID terminology transfer was observed from science to humanities during the same period.

Corpus linguistics also enabled the identification of the most the common synchronic BID morphemes which provided a basis for lexical and semantic analysis. Specifically, the identification of conceptual domains and their structure. BID conceptual domains were plotted against the known and established framework of academic disciplines, this revealed a complex web of interactions between all disciplines.

The semantic differences between bio -mimetic(s), -mimicry were challenged during the evaluation of the proposed mapping system. Within this context, the terms appear to offer no useful information or insight. The proposed domain-based framework enables the positioning of research and practice within a network of known and established disciplines in a way that provides a transparent and well-founded basis for the development of new concepts and theories, void of buzzwords.

The mapping system was adapted to include biodesign and bioart. A deeper analysis of the terms via corpus-linguistics challenged the semantic properties of each term. Honing in on the biodesign space revealed a much different picture to the sematic value attributed from the corpus search results. This triggered the need for deeper analysis. As such, specially selected case studies were analysed using the novel mapping system as a framework. The findings highlighted an extraordinarily complex system of interaction between a wide range of disciplines.

This study suggests that we should regard the BID landscape as a spectrum composed of a complex network of interdisciplinary actions. Also, further work is required to provide deeper understanding of the relationship between sustainable and circular principles within the wider context of the BID.

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	total tokens	unique words
1960-74	124	16
1975-84	591	46
1985-93	8766	480

Table 1. Chronological view of the total number of times a bio- term appears within the selected corpus (total tokens) and corresponding number of unique words within the token range.

	Total tokens	Unique word forms
Wiki	490,570	6,531
iWeb	1,987,972	8,766

Table 2: Chronological view of the total number of times a bio- Term (total tokens) within the selected corpus and number of unique bio terms (access date 26th October 2020).

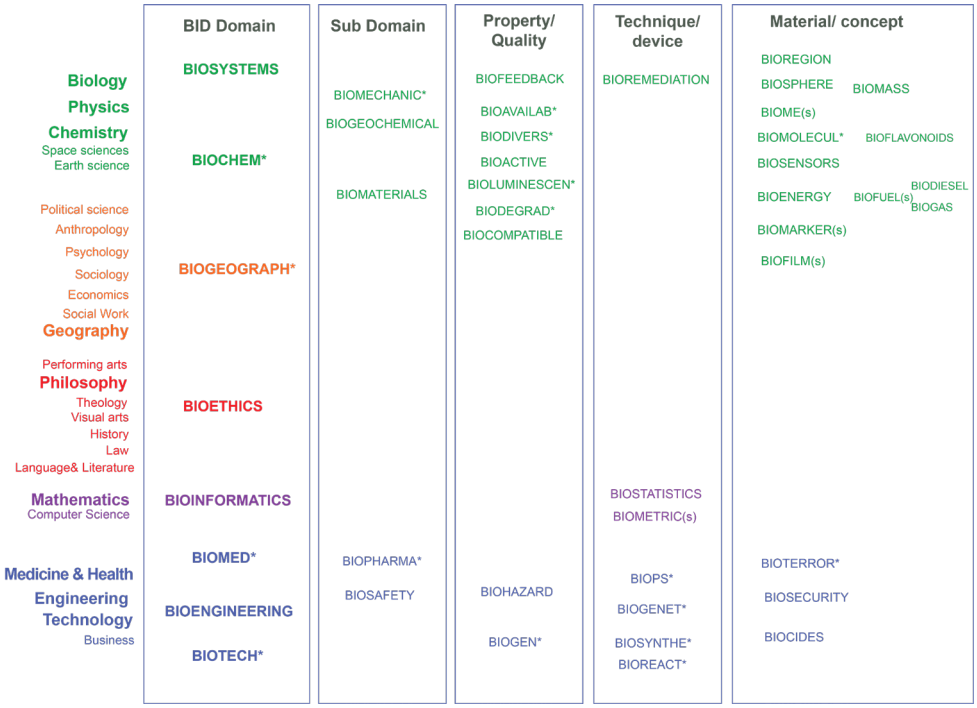


Table 3. BID scientific terms and key conceptual domains from analysis of 100 most frequent BID terms from wiki and iWeb corpuses.

	Morphology	source:	access date
biomimetics	βίος (bios), life, and μίμησις (mīmēsis), imitation, from μιμεῖσθαι (mīmeisthai), to imitate, from μῖμος (mimos), actor	Wikipedia	22/10/2020
biomimetic	same as above		22/10/2020
biomimicry	βίος (bios), life, and μίμησις (mīmēsis), imitation, from μιμεῖσθαι (mīmeisthai), to imitate, from μῖμος (mimos), actor	Wikipedia	22/10/2020

Table 4. Morphology of biomimetic(s) and biomimicry.

Case	Academic domain	Academic sub-domain	BID domain	sub-domain 1	sub-domain 2	material/ concept	tech/device	quality/ property
TET	Arts and humanities	Textile design-craft	Biotechnology	tissue engineering		Tissue engineered Textiles	tissue scaffold construction	
PK	Arts and humanities	Textile design-knit	Botany	Materials engineering	Biosystems	programable knit	knit	hygroscopic shape change
BC	Arts and humanities	Textiles design - non-woven	Biotechnology		Biosystems	bacterial cellulose materials for fashion	fermentation/ textile and garment processing	Bio-degradable
MT	Arts and humanities	Textiles design - non-woven	Biotechnology	Applied Mycology	Biosystems	mycelium materials for textile applications		Bio-degradable
HT	Arts and humanities	Textile design	Botany	Engineering design	Materials engineering	hygroscopic textile units	thin films, weaving	hygroscopic shape change

Table 5. Analysis of design led BID practice on the topic of textiles using the domain framework.

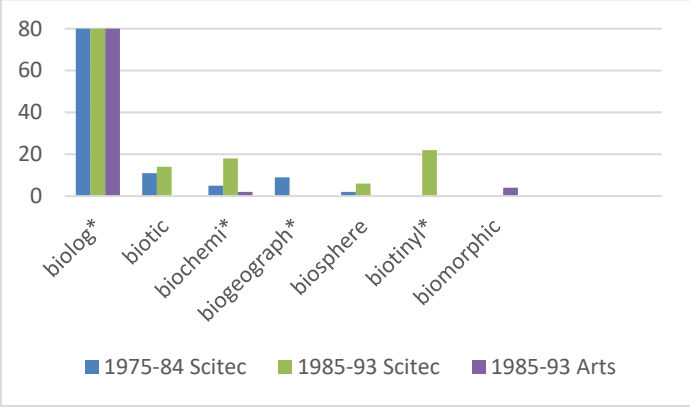
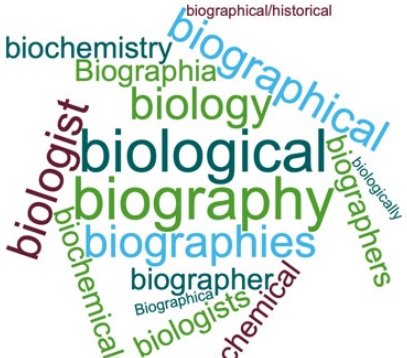
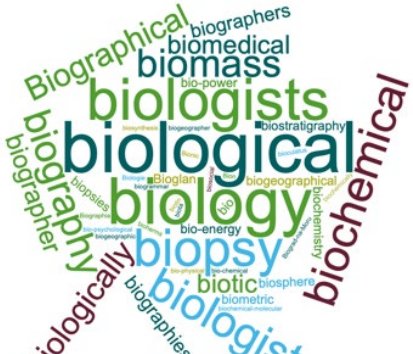
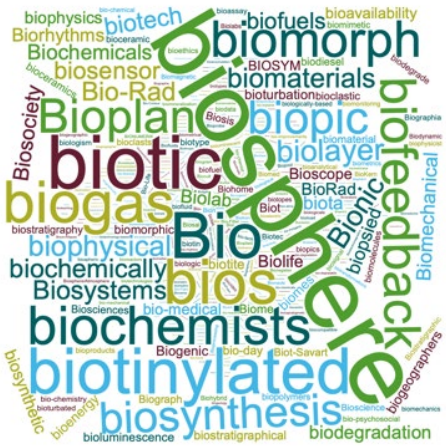


Figure 1. Chronological view of the most common Bio- morphemes according the genre.





a b



c

Figure 2. Word cloud images showing the range of bio- terms per chronological period: a.1960-74, b.1975-84, c.1975-1993

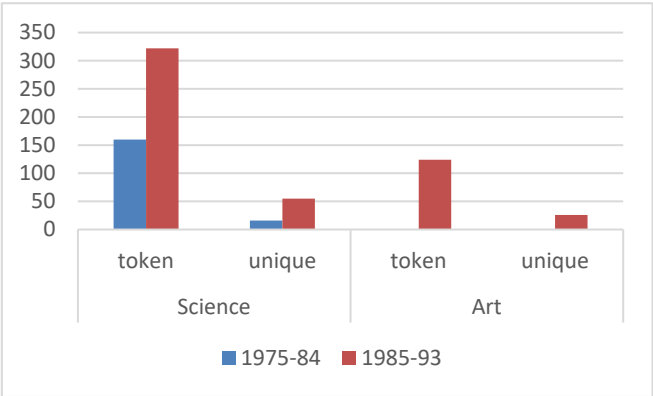


Figure 3. Chronological view of the total number of times a bio- term appears within each genre (total tokens) and corresponding number of unique words.

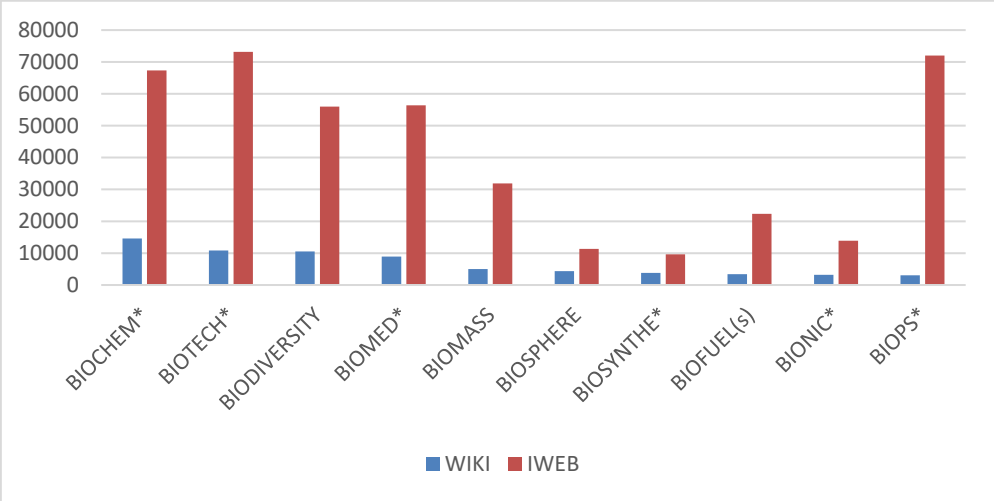


Figure 4. List of the most popular distinct morphemes from corpus search.

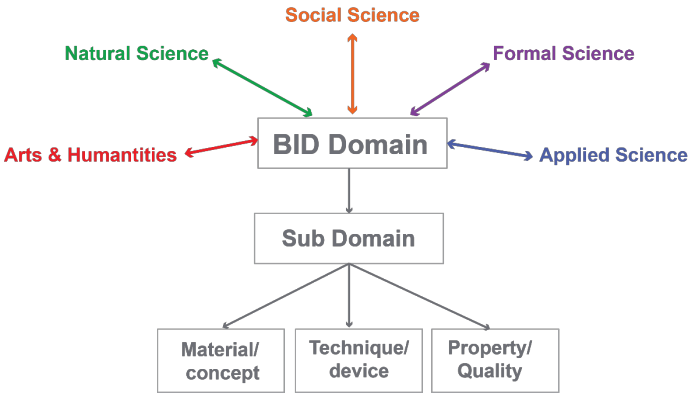


Figure 5. Proposed structure of BID conceptual domains

Figure 6. Map of BIDs framed within academic discipline domains; further inter-connections between BID domains are expressed via dotted line.

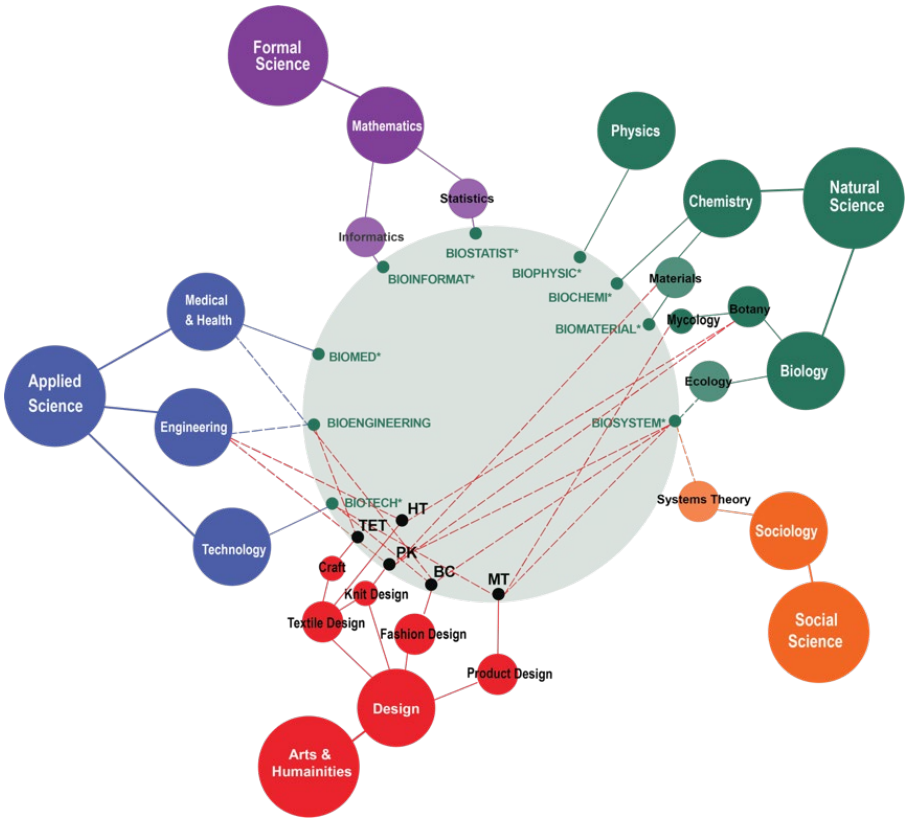


Figure 7. Positioning of five design-led examples within the BID map using a domain-based framework.