PHILOSOPHICAL PSYCHOLOGY
2024, VOL. 37, NO. 8, 1995–2018
https://doi.org/10.1080/09515089.2022.2113770

ARTICLE

Connecting the methods of psychology and philosophy: Applying Cognitive-Affective Maps (CAMs) to identify ethical principles underlying the evaluation of bioinspired technologies

Philipp Höfele[a,b†], Lisa Reuter[c†], Louisa Estadieu[d,e], Sabrina Livanec[c,d], Michael Stumpf[c,d] and Andrea Kiesel[c,d]

[a]Department of Philosophy, Pennsylvania State University, State College, Pennsylvania, USA; [b]Institute of Philosophy, Freie Universität, Berlin, Germany; [c]Institute of Psychology, University of Freiburg, Freiburg, Germany; [d]Cluster of Excellence livMatS @ FIT – Freiburg Center for Interactive Materials and Bioinspired Technologies, University of Freiburg, Freiburg, Germany; [e]Department of Philosophy, University of Freiburg, Freiburg, Germany

ABSTRACT
One major challenge of the 21st century is the increasingly rapid development of new technologies and their evaluation. In this article we argue for an interdisciplinary approach to meet this demand for evaluating new and specifically bioinspired technologies. We combine the consideration of normative principles in the field of ethics with psychological-empirical research on attitudes. In doing so, the paper has a twofold concern: first, we discuss how such an interdisciplinary collaboration can be implemented by using the method of Cognitive-Affective Mapping. Cognitive-Affective Maps (CAMs) enable a graphical representation of attitudes, including cognitive and affective aspects. Second, we argue that CAMs can be helpful to remedy the deficits of traditional ethical approaches. We applied CAMs in the context of an ethics seminar in which students were instructed to create CAMs based on bioinspired technologies twice – prior to the seminar to assess their evaluation on bioinspired technologies per se (pre-assessment) and after the seminar to assess how their evaluation might have changed and especially which normative ethical principles might have been additionally considered (post-assessment). As could be shown, CAMs can visualize the students' attitudes, including the valence of ethical principles. Further, comparing pre- and post-CAMs indicated students' attitude change.

ARTICLE HISTORY
Received 17 April 2022
Accepted 11 August 2022

KEYWORDS
Evaluation of bioinspired technologies; ethical principles; interdisciplinarity; cognitive affective mapping; empirical ethics

CONTACT Philipp Höfele philipp.hoefele@fu-berlin.de Institut für Philosophie, Freie Universität Habelschwerdter Allee 30, Berlin, Berlin D-14195, Germany; Lisa Reuter lisa.reuter@psychologie.uni-freiburg.de Cluster of Excellence livMatS @ FIT – Freiburg Center for Interactive Materials and Bioinspired Technologies, University of Freiburg Georges-Köhler-Allee 105, Freiburg D-79110, Germany

†These authors are shared first authorship.

This article has been corrected with minor changes. These changes do not impact the academic content of the article.

1. Introduction

In view of the ecological challenges of our present age, bioinspired technologies, i.e., technologies that imitate functional principles of nature, and the associated research fields of biomimetics or biomimicry, are increasingly important as future technologies (Benyus, 2002). Yet, the transfer of functions from biological models to technical applications does not guarantee that the applications are good for humans or for the environment. Therefore, this transfer is not well-suited considering normative aspects – biomimetic products are not per se better, more ecological and less risky technical solutions. To determine whether the 'biomimetic promise' (von Gleich et al., 2010) of better, more ecological and less risky technical solutions is kept, it is necessary to implement a second step of reflection, which considers the products independently of their pure imitation of biological functions (Möller et al., 2020). For this reflection, ethical principles must be identified, as is done in particular in the context of ethics and technology assessment (Grunwald, 1999; Jonas, 1984). Yet, abstract ethical principles are usually no longer sufficient to rate new technologies (Kibert et al., 2012) because technologies are being developed ever faster and at the same time penetrate the natural and social life world ever more comprehensively. Therefore, in addition, the normative perspectives of users and affected laypersons are increasingly included in the process of adequate normative decisions about these technologies (Molewijk et al., 2004; Paulo & Bublitz, 2020).

In this article, we endorse an interdisciplinary approach to meet this double standard for new and, in our case, bioinspired technologies. We combine psychological-empirical acceptance research with the consideration of normative principles by ethics and technology assessment to address the far-reaching challenges of new technologies. Here, the methods of psychology appear promising in capturing normative concerns from users and affected persons who exhibit attitudes on a culturally specific, group-specific or even individual-specific level. This should be taken into account in the development of new bioinspired technologies (Höfele, 2022).

In the following, we discuss such an interdisciplinary cooperation in the application of the method of Cognitive-Affective Mapping (Thagard, 2010). Cognitive-Affective Maps (CAMs) allow to connect beliefs, impressions, ideas, and emotions about a particular topic in a network-like structure. While in questionnaires and interviews the researchers' item and question formulations often prescribe specific linguistic-semantic thought structures, the CAM method allows for a very free collection of individual attitudes, less influenced by suggestive wordings. One advantage with respect to other types of cognitive modeling of knowledge is that each CAM concept carries an affective value, involving three gradations of positivity and negativity, and one option each for neutrality and ambivalence. A more detailed description of the method of Cognitive-Affective Mapping follows in the methods section. By using this method, we explore two central questions:

First, we test the extent to which moral evaluations and ethical principles are explicitly or implicitly reflected in CAMs created by laypersons (students) on the topic of bioinspired technologies.

Second, we want to find out whether a scholarly engagement with issues around ‘ethics of nature’ in the context of an ethics seminar leads to changes in the individual CAMs of the students.

In the following, the theoretical background about the role of psychology as well as that of philosophy, especially its subfield of ethics, will be presented first. We will then suggest the methodology of Cognitive-Affective Mapping for ethical reflections, while at the same time serving to remedy a deficit of traditional ethics. Traditional ethics often take a top-down approach and do not take into account different contexts and concerns of groups of people (chap. 2). We elaborate on this issue by discussing the application of the Cognitive-Affective Mapping method in the context of an ethics seminar. Here the students were given the task of drawing a CAM on the subject of bioinspired technologies twice – once at the start of the semester and once at the end of the semester (chap. 3 and 4). Subsequently, we reflect on the methods of psychology and philosophy more fundamentally. Our aim is to illustrate the interdisciplinary cooperation of both disciplines in the context of the evaluation of bioinspired technologies as an interplay of hypothesis-guided and hermeneutical procedures. This interplay is intended to remedy the aforementioned deficit of traditional ethics in that psychology helps to establish empirically informed ethics (chap. 5). A short outlook concludes the article (chap. 6).

2. Psychological research on attitudes and attitude change as a methodological enrichment of empirical ethics

CAMs represent various cognitive and affective aspects of a topic, in other words, they visualize individuals’ attitudes as a network of relevant concepts (also referred to as nodes), their respective affective connotation, and certain relationships between the concepts (links). The notion of attitude has been extensively researched in social psychology for decades, although the distinction from other terms, for example, *beliefs*, *opinions*, *values*, is often ambiguous (Seel, 2012). According to Ajzen (2001), an attitude represents the summarized evaluation of a psychological object. With respect to the neurosciences, conceptions of attitudes envision a network of nodes with affective and cognitive connotations connected by associative pathways (Seel, 2012). Here we work with one specific form of such networks – the CAMs introduced by Thagard (2010). Thagards Cognitive-Affective

Mapping method builds on his computational HOTCO model, which uses artificial neural networks to explain inferences influenced by emotions (Thagard, 2006, 2012, 2015).

Numerous researchers have attempted to model not only attitudes, but also their change. Some theories are called consistency theories, e.g., Festingers *cognitive dissonance theory* (Festinger, 1957), Heiders *balance theory* (Heider, 1958), or Bems *self-perception theory* (Bem, 1967). These theories do not imply that attitudes are unchanging, but rather state that people strive for consistency in their cognitions and are motivated to resolve inconsistencies, e.g., by changing individual attitude components.

Similarly, Thagards theory of emotional coherence states that people strive for such a coherence, not only for cognitive but also for emotional coherence, since reasoning is based not only on logical arguments, but also on emotions (Thagard, 2006). Consequently, Thagard distinguishes between cognitive incoherence and emotional incoherence. In detail, incoherence may arise from the fact that two actions or goals contradict each other, i.e., it is not possible to perform or achieve both. And incoherence may also result due to a connection between elements in which a good feeling about one element simultaneously comes along with bad feelings about the other element (Thagard, 2010).

An attitude change can then be explained by the motivation to increase coherence. Please note that other researchers have also developed and empirically tested theories on attitude change (for an overview, see Lorenz et al., 2021; Seel, 2012). Although these theories offer different explanations for the mechanisms of attitude change, they overlap in saying that attitude change is possible and arguably influenced by an interplay of cognitive, emotional, and behavioral elements, and that attitudes can vary in strength (Seel, 2012). One factor influencing attitudes is knowledge, also referred to as attitude-relevant knowledge (Fabrigar et al., 2006). Fazio (2007) refers to attitudes themselves as evaluative knowledge, as a sum of evaluations, influenced among other things by the information available. At this point we consider it important to note that the impact of information on attitudes is mutual: the influence of attitudes on availability of information (in terms of retrieving information from memory) or search for information (in terms of encoding information) is widely researched and well-known as confirmation bias (e.g., Festinger, 1957; Hart et al., 2009; Wason, 1960).

As stated above, one goal of our study is to explore the influence that information about the 'ethics of nature' (in the form of philosophical considerations in an ethics seminar) can have on students' attitudes toward bio-inspired technologies, i.e., nature imitation in technology development. To our knowledge two recent studies used related methods. In these studies, the influence of ethical values in the case of different stakeholders has been mapped by value-informed mental models (ViMMs) in the context of climate risk management (Bessette et al., 2017; Mayer et al., 2017). The difference of their approach to the ethical application of the CAMs in our study, is that CAMs are drawn by each member of the investigated group himself and that CAMs also depict emotional attitudes.

CAMs have already been used in practical-political and ethical contexts. Thagard introduced CAMs in the context of conflict research and explains how they can help to better understand the conflicting positions of opponents. Homer-Dixon et al. (2014) demonstrated that CAMs can be used to represent the beliefs of individuals in disputes as diverse as the dispute over German housing policy, disagreements among Israelis over the meaning of the Western Wall, disputes over the exploitation of Canadian bitumen deposits, as well as the dispute between proponents and opponents of action on climate change. In our study, however, we used a slightly different variant of CAMs. Specifically, we added the ability to connect concepts by arrows to depict a unidirectional connection (connections are also referred to as links). Figure 1 shows an exemplary CAM on nature imitation in technology development.

Initially, CAMs were mostly drawn by the researchers themselves to visualize specific perspectives or existing data material (e.g., Findlay & Thagard, 2014; Homer-Dixon et al., 2013, 2014; Luthardt et al., 2020; Wolfe, 2012). More recently, CAMs have also been used as a survey method by having participants draw CAMs themselves on a particular

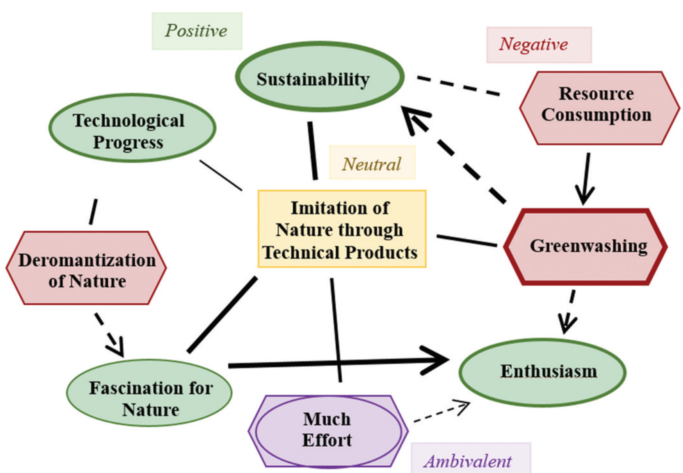

Figure 1. Exemplary CAM on the topic "Imitation of nature through technological products". Valences of the concepts are represented by the nodes' shapes and colours. Green ovals = positive affect; red hexagons = negative affect; yellow rectangles = neutral affect; purple superimposed hexagons with ovals = ambivalent affect. For green and red shapes, strength of the shape's border denotes a grading of the affective connotation (range = 1, 2, 3) – the thicker the frame, the more positive/negative the concept. Two types of links indicate the relations between concepts. Solid lines = supportive connections; dashed lines = inhibiting connections; arrowheads = one-sided/unidirectional influence; without arrowhead = mutual influence.

topic (e.g., Mansell et al., 2021; Reuter, Mansell et al., 2022). Livanec et al. (2022) proposed CAM as a vivid, practical tool of collaborative knowledge production between scientific and nonscientific stakeholders in the context of technology acceptance prediction. Thagard (2015) used CAMs to visualize attitudes of students in an ethics seminar and concluded that the method is suitable for this purpose. He explained how philosophy students were instructed to draw CAMs on seminar topics. We will describe Thagard (2015) study in more detail since we modified his approach for our application of CAMs.

The students of an environmental ethics course and a medical ethics course taught by Thagard were asked to draw CAMs on one of seven yes/no ethical questions they could choose from. Questions included 'Are publicly funded drug injection sites morally right? Yes or no'. (Medical Ethics) or 'Is the use of genetically modified organisms morally wrong? Yes or no?' (Environmental Ethics). Each student was asked to draw one map in favor of the position, as well as one map against it. Ultimately, they were asked to rate their experience with the method in a post-survey. The results of this survey suggest that on average students found the method helpful, both for their general understanding of the topics as well as for gaining other perspectives on them. Students also supported the use of the method in future seminars. One question referred to how often the students' opinion changed as a result of drawing the CAMs (answer options: 0, 1, 2, 3). More than 80% of the students stated that they had changed their opinion at least once – the mean values were 1.08 (Medical Ethics) and 1.13 (Environmental Ethics). According to Thagard, the method is easy to use and informative about the structure of ethical conflicts. Thagard thus also indirectly shows that ethical laypeople, or at least undergraduate students in ethics, can use CAMs to make their ethical principles explicit.

This approach stands partly in contrast to classical ways of approaching ethics. Many classical approaches intend to consider ethical principles for action that are not dependent on subjective or individual attitudes, but can apply in a universally accepted manner (Pieper, 2007). Furthermore, these approaches often seek to strictly separate ethical rationality and emotions (e.g., Kant, 2019; van Roojen, 2009), whereas Thagard (2015) used CAMs to make a connection visible, emphasizing that rational judgments imply emotional reactions. Furthermore, it has been shown, especially in the context of medical ethics (Musschenga, 2005, 2009), but increasingly also in other areas of ethics (Birnbacher, 1999), that ethics must integrate sociological and psychological data. This is the only way to ensure that ethical principles of action are applicable to specific realities. Therefore, '[e]mpirical ethics combines doing empirical – usually qualitative – (social) research with philosophical (normative ethical) analysis and reflection' (Musschenga, 2005, p. 468). Of course, this raises the question of how such empirical-qualitative research can be conducted and how the implicit normative beliefs and judgments of persons can be made visible. For example, empirical ethics assumes that many moral judgments are made intuitively, and the individuals are not able to take a reflective position on their judgments (Paulo & Bublitz, 2020). CAMs represent a method to make such moral judgments or conflicts and the accompanying values visible, which is why Thagard (2015) also speaks of 'value maps'.

In the following, this is demonstrated by means of an ethics seminar in which CAMs were also used as in Thagards case. While Thagards students were instructed to draw CAMs on morally difficult yes/no-questions and used only negative and positive evaluations, we made some changes that will be explained in detail in the next chapter.

In summary, the specific questions of our study are: 1a) Can CAMs be used to map students' attitudes toward nature imitation in technology development? 1b) Can ethical principles be identified in such CAMs? 2a) Do the attitudes represented in CAMs change over the course of the seminar? 2b) Are these changes specifically related to the content of the seminar? The example of the ethics seminar also illustrates the extent to which interdisciplinary cooperation between psychology and philosophy in particular can put the concern of empirical ethics into practice.

3. CAMs in the context of an ethics seminar: Application of the method

3.1. CAMs Data collection

Data collection took place as part of a winter term seminar 2020/21, entitled '*Sustainability and its Ethical-Philosophical Foundations*'. The seminar reflected on the ethical-philosophical foundations of the concept of sustainability. Its content was closely related to the topics of natural and environmental philosophy, the ethics of responsibility, as well as approaches of biocentrism and deep ecology (Krebs, 2016a; Muraca, 2016; Schopenhauer, 2004; cf. in detail Supplementary Material 1). Students taking part in this seminar mainly pursued degrees in philosophy, and tended to be at the beginning of their bachelor studies. We assumed that they did not have intensive contact with such topics before the seminar and considered them as laypersons when drawing the first CAM on the topic of nature imitation in technology development at the beginning of the semester. We conjectured that engaging with the themes of the seminar might influence their attitude toward nature imitation in technology development. The students were asked to create one CAM at the beginning of the semester (pre-CAMs) and one at the end of the semester (post-CAMs) on the topic of nature imitation in technology development. While Thagards students were instructed to create two CAMs (one pro/one con) and advised not to include two perspectives in one CAM, we asked students to draw only one CAM at a time and this CAM was to reflect their own perspective. While Thagard gave further specific guidelines (for example, a minimum of positive/negative nodes; no ambivalent nodes, etc.), we gave only a general instruction on drawing a CAM without restrictions or minimum requirements.

In detail, students were instructed online using Unipark before the first content-related seminar date (full instructions can be found in the Supplementary Material 2a & 2b) on how the Cognitive-Affective Mapping method and the Valence[1] software (Rhea, Reuter, Thibeault et al., 2021) work. Valence is a freely available online tool for creating CAMs. Next, students read a text with information about nature imitation in technology development (Appendix) and were asked to create a CAM with the Valence software based on the question 'What are your thoughts and evaluations regarding nature imitation by technological products?'. When starting Valence with their personal software access, a central node with the content 'Nature Imitation through Technical Products' was shown and the students were asked to create their own CAM around this concept. Students were free to choose the time of CAM creation in the period Oct. 27– 2 November 2020. The same procedure was repeated at the end of the semester (period of CAM creation: Jan. 21– 8 February 2021). The anonymous data collection was unable to trace back the CAMs to the students. The pairing of pre- and post-CAMs was realized by an individual code. 32 students were assigned to the seminar. We received N = 62 (nt1 = 34; nt2 = 28) assignments to the software, of which we could match N = 36 CAMs, which resulted in N = 18 CAM pairs that could be analyzed. The remaining CAMs could not be used because they either showed deficiencies (for example, no connections between nodes; wrong topic), or codes could not be matched.

3.2. CAMs Analyses

There is no gold standard for the analysis of CAMs, instead different approaches have been explored by researchers, both quantitative and qualitative (Reuter, Fenn et al., 2021). The high degree of freedom while creating CAMs resulted in rather heterogeneous CAMs. We therefore decided to use a two-part rating procedure. One rating was related to the ethical-normative principles in both pre- and post-CAMs, the other rating concerned the general differences of the nodes' content and valence. Both rating procedures will now be described.

3.2.1. Ethical Principles

To investigate whether we can use CAMs not only to map students' attitudes regarding nature imitation in technology development (research question 1a), but also to identify ethical principles relevant to students (research question

1b), we created a list of 20 ethical principles (Supplementary Material 3). This list was mainly based on a text on the ethics of nature by Angelika Krebs and a text on the sustainability discourse by Barbara Muraca (Krebs, 2016b; Muraca, 2010).[2] The list was only definitively established after reviewing all CAMs drawn by students. Only those of Krebs (2016b) principles concerning the ethics of nature that were mentioned in the CAMs were then included in the list; principles from Krebs (2016b) that were not mentioned in the CAMs were omitted from the list. In addition, other principles were identified, particularly those of the ethics of sustainability, which are mentioned in the text by Muraca (2010). These were also included in the list. Methodologically, we followed the approach of the hermeneutic circle (cf. below chap. 5.3.) to ensure that the CAMs did not only show the ethical principles pre-selected by the raters and that no ethical principles were left out.

Subsequently, the CAMs were rated by noting which principles appeared in each individual CAM. Initially, to answer research question 1b, no attention was paid as to whether a single CAM was created before the start of the seminar (pre-CAMs) or at the end of the seminar (post-CAMs). To allow for some sort of inter-rater reliability, two raters were instructed independently. Both raters, graduate students of philosophy and research assistants at the Department of Philosophy, received the list of the ethical principles, as well as the text on the ethics of nature (Krebs, 2016b), which contained explanations of the principles. The raters were instructed to pick out ethical principles explicitly mentioned in the CAM nodes, i.e., ethical principles that were more or less precisely mentioned in the wording of Krebs (2016b) and Muraca (2010). They were also asked to name nodes in the CAMs that they thought implicitly addressed ethical principles – without being precisely mentioned in the wording of Krebs (2016b) and Muraca (2010). In addition, no further instructions for categorization were given, contrary to the usual procedure in content analysis. Definitions of and distinctions between the categories emerged from the description of the principles themselves in Krebs (2016b). After the individual ratings, the raters exchanged ideas to discuss differences and, if possible, to reach a joint judgment (see also Mayring, 2020; Scott, 1955). Raters quickly came to agreement on the few differences in their ratings.

3.2.2. CAMs Differences results from using the CAMs in the context of an ethics seminar

To analyze systematic differences between the pre- and post-CAMs (research question 2a), we formed deductive categories according to which we evaluated differences between the CAMs. The creation of deductive categories is mainly known from qualitative content analysis (e.g., Mayring, 2020). However, our procedure differs fundamentally from the typical application of deductive categories, which is primarily designed for text material, such as interviews.

Table 1. Template for the Rating of Differences between the pre- and post-CAMs.

Content:					
Are there new terms in the second CAM?					
Are terms omitted in the second CAM?					
Do terms remain the same?					
Response Categories:					
None		Some		Many	
Valence:					
Does the overall valence change?					
Does the valence of the original concept (nature imitation in technical products) change?					
Does the valence of the consistent terms (if existing) change?					
Response Categories:					
No	Yes, more positive afterwards	Yes, more negative afterwards	Yes, more neutral afterwards	Yes, more ambivalent afterwards	Neither, but . . .

The template was translated into English, see Supplementary Material 4 for the original version.

Our categories are not semantic-based but focus on the structure and the affectivity of the CAMs (Table 1). In order to grasp differences between the pre- and post-CAMs on different scales, the categories were created by the research team. Then two raters, a graduate student of psychology and a bachelor student of education, both research assistants of the Psychological Department, independently rated each pair of CAMs according to the categories. Since the raters had the option to inductively add categories, the two categories 'wordiness' (How wordy are the concepts?) and 'complexity' (How complex is the overall representation of the CAM?) were added. There were only slight differences between the raters' scores, which could be eliminated in the exchange.

In addition to the rating, we analyzed each CAM regarding network parameters with an open source code (Rhea, Reuter, Tecza et al., 2021). This software features the assessment of emotional parameters such as the mean valence of a CAM map as well as structural parameters such as density. For the full list of parameters that we assessed see chap. 4.1., Table 2.

Finally, the pre- and post-CAMs were also compared regarding the ethical principles mentioned in them. It was not only evaluated which and how many ethical principles were mentioned in the pre- and post-CAMs, but also examined whether ethical principles were mentioned only implicitly or explicitly (i.e., in the wording of Krebs, 1999; Muraca, 2010) in the pre- and post-CAMs.

4. Results from using the CAMs in the context of an ethics seminar

In general, it can be stated that the CAMs reflect the students' attitudes regarding nature imitation in technology development (research question 1a). Indeed, most of the CAMs entailed many concepts (ranging from 4 to 24, on average ca. 12) and different emotional evaluations of the nodes. In

Table 2. Frequency of rating categories used per rater.

New Terms	0 (None)	1 (Few)	2 (Many)				
Rater 1	1	2	15				
Rater 2	3	8	7				
Omitted Terms	**0 (None)**	**1 (Few)**	**2 (Many)**				
Rater 1	0	8	10				
Rater 2	3	7	8				
Remaining Terms	**0 (None)**	**1 (Few)**	**2 (Many)**				
Rater 1	6	11	1				
Rater 2	12	5	1				
Overall Valence *Second CAM more ...*	**Neutr.**[a]	**Amb.**[b]	**Pos.**[c]	**Neg.**[d]	**Same**		
Rater 1	3	5	5	2	3		
Rater 2	6	5,5	5,5	1	0		
Valence Remaining Concepts *Second CAM more ...*	**Neutr.**[a]	**Amb.**[b]	**Pos.**[c]	**Same**	**No Remaining Concepts**	**More Extreme**	**Other**
Rater 1	-	2	-	8	6	1	amb. + pos. + neg. (1)
Rater 2	1	7	1	6	2		amb. + pos. (1)
Valence of Original Concepts *In second CAM more ...*	**Same**	**Deleted**	**Amb.**[b]	**Missing (in both CAMs)**			
Rater 1	9	4	3	2			
Rater 2	11	4	3	-			
Wordiness *Second CAM is ...*	**Much Less Wordy**	**Less Wordy**	**Equally Wordy**	**More Wordy**	**Much More Wordy**		
Rater 1	3	3	10	-	2		
Rater 2	3	4	6	4	1		
Complexity *Second CAM is ...*	**Much Less Complex**	**Less Complex**	**Equally Complex**	**More Complex**	**Much More Complex**		
Rater 1	3	6	5	3	1		
Rater 2	3	7	2	5	1		

[a]Neutr. = Neutral; [b]Amb. = Ambivalent; [c]Pos. = Positive; [d]Neg. = Negative. Most frequent categories are highlighted.

addition, when evaluating the CAMs, numerous implicitly or explicitly mentioned ethical principles could be identified in the students' CAMs (research question 1b). In addition, significant differences in the pre- and post-CAMs could be detected (research question 2a) in both the evaluation based CAM differences and based on hermeneutic analyses of ethical principles, as will be discussed in more detail below. Furthermore, these differences could be attributed to the contents of the seminar (research question 2b).

4.1. CAMs Differences

In general, it can be stated that students' CAMs differed substantially in pre/post comparison. Regarding the terms used in both CAMs, many new concepts were added, while others were dropped and, in comparison, few concepts remained the same. An overview of the final rating of differences between the CAMs is presented in Table 2, the detailed ratings per CAM can be found in the Supplementary Material 5.

Regarding the concepts' valence, both raters from the Department of Psychology identified a tendency that CAMs were more ambivalent, neutral and positive in their overall valence at the post-assessment compared to the pre-assessment. The valence of the original concept ('Nature Imitation through Technical Products') remained the same, which is likely due to the fact that the majority of original concepts were drawn neutrally. This particularity could in turn be attributed to the effect of the exemplary CAM in the instruction, in which the central/original concept was represented as a neutral node. Also, when the students logged into the software, the original concept was neutral and it might not have been clear for them that they could change the valence of the central concept.

Two categories give an idea of the extent to which the pre-/post-CAMs are similar in appearance. The category wording indicates some sort of formal stability in the CAMs, as students did tend to express themselves with similar words in each of the CAMs according to both raters. In terms of complexity, both raters noted a slight reduction in complexity.

For the mentioned categories the raters' most frequent response options corresponded to each other. For the following categories the ratings differed: Regarding the evaluation of the valence of the unchanged terms only one rater had the impression that a majority of these concepts' valences changed to ambivalent while both raters noted no changes for a large proportion of remaining concepts. Although the ratings were similar in their frequency concerning (un)changed terms, the difference could be due to the fact that, the raters sometimes rated different terms as remaining the same and this could be reflected in the (ambivalence) valence ratings of these terms.

The calculated parameters (Table 3) support the raters' impression that ambivalent and neutral nodes appeared more frequently in the post-CAMs than in the pre-CAMs. The parameters also reveal that the post-CAMs

Table 3. Calculated Network Parameters of pre-CAMs and post-CAMs and the difference between them.

Network Parameters	Pre-CAM Mean Value	Post-CAM Mean Value	Difference (Post − Pre)
Increase			
Nodes (All)	12,67	12,83	0,16
Nodes Ambivalent	0,94	2	1,06
Nodes Neutral	2,89	3,67	0,78
Links (All)	15,28	15,83	0,55
Links (Solid)	12,61	14,06	1,45
Mean Valence	0,24	0,45	0,21
Density[a]	0,23	0,26	0,03
Decrease			
Negative Nodes	3,83	2,33	−1,5
Positive Nodes	4,94	4,83	−0,11
Links (Dashed)	2,67	1,78	−0,89
Diameter[b]	4,5	4,44	−0,06

[a]All Links of a CAM divided by the number of possible links in the CAM; [b]Longest path in the CAM without repeated visits of nodes.

contained more solid links but fewer dashed links. The CAMs' mean valence and amount of nodes was slightly increased in post-CAMs. The decrease of negative nodes in post-CAMs was higher than the decrease of positive nodes. For the latent parameters of density and diameter there was almost no change, indicating that latent parameters show more stability than emotional parameters.

4.2. Ethical Principles

The ethical-philosophical evaluations of the students' CAMs likewise indicate differences between the pre- and post-CAMs regarding three aspects: First, more principles from the ethics of nature were mentioned by the students in the post-CAMs. Second, explicitly mentioned principles were found exclusively in the post-CAMs, i.e., principles that more or less correspond in wording to the principles from the ethics of nature listed in Krebs (2016b) and Muraca (2010), which may be due to the preoccupation with these principles in the context of the ethics seminar. Third, and in general, it can be stated that slightly more implicitly and explicitly mentioned principles could be identified in the post-CAMs than in the pre-

Table 4. Illustration of the frequency of implicitly and explicitly stated ethical principles in CAMs.

Ethical Principles	Quantity of naming a principle in pre-CAMs	Quantity of naming a principle in post-CAMs	Explicitly named principles (*onlyin post-CAMS)*
1. Anthropocentric argument/value of rationality/human beings	2	5	5
2. Aisthesis argument/multifunctionality of nature	1	3	1
3. Argument of aesthetic contemplation	4	3	0
4. Argument of the capability approach/of the good life	1	2	1
5. Argument of human hybris	1	4	2
6. Argument of weak sustainability/three-pillar model	1	3	2
7. Argument of strong sustainability/dependency argument/ biosphere as resource/boundary	2	4	2
8. Autonomy argument	2	2	1
9. Basic needs argument/argument of survival'	0	3	1
10. Biocentrism argument/value of life	0	2	1
11. Design argument	6	1	0
12. Harmony argument	2	3	0
13. Holism argument	1	2	0
14. *In dubio pro malo* argument (Jonas' 'heuristic of fear')	7	3	0
15. Intergenerational justice	0	3	1
16. Intragenerational/social justice	2	2	0
17. Naturam sequi argument	9	6	0
18. Pedagogical argument	2	2	0
19. Pathocentric argument/value of sentient beings	2	1	0
20. Physiocentric argument/value of being/nature	1	5	4
Total	**46**	**59**	**21**

Participants mentioned more principles in the post- than in the pre-CAMs. Additionally, the principles (according to Krebs, 2016b; Muraca, 2010) are mentioned explicitly only in the post-CAMs.

CAMs. Table 4 shows in detail the frequency of individual principles in the pre- and post-CAMs and also identifies CAMs where ethical principles were explicitly mentioned by students (in or close to the wording of Krebs, 2016b; Muraca, 2010). A full overview over principles mentioned in the CAMs can be found in the Supplementary Material 6. Supplementary Material 7a & 7b contains a precise mapping of all CAMs' nodes to ethical principles, which lists nodes identified as implicitly naming ethical principles.

Due to the large number of only implicitly mentioned principles, especially in the pre-CAMs, the independently evaluating raters from philosophy delivered different evaluation results in view of some CAMs. Frequently, only the subsequent discussion of the evaluation results among the two raters could lead to a uniform evaluation result. The problem described here also refers back to the difficulty that CAMs represent mental structures only on the basis of briefly formulated concept nodes. Thus, an interpretative effort on the part of the raters is required.

5. Discussion: The advantages of an interdisciplinary approach to the evaluation of bioinspired technologies

With our open, interdisciplinary empirical approach, we were able to gain more insight into the attitudes of philosophy students toward bioinspired technologies, which are discussed below. Subsequently, we reflect on the process of how we brought together the disciplinary different patterns of thinking and research.

5.1. Exploring attitudes with CAMs

Our research question 1a) was whether it is possible to use Cognitive-Affective Mapping to represent students' attitudes toward the topic of nature imitation in technology development. Based on the fact that students drew rich CAMs (on average about 12 nodes and 15 connections per CAM) and used the opportunity to effectively evaluate the concept nodes, we conclude that the CAMs were useful for the students to create a vivid representation of their perspectives. Further, we asked in question 1b) whether ethical principles can be identified in such CAMs. This was clearly the case as the raters of philosophy were able to identify implicitly and explicitly named ethical principles in pre- and post-CAMs. Question 2a) addressed whether attitudes represented in the CAMs differed from the first data collection at the beginning of the semester to the second one at the end of the semester. Here the CAMs changed from the first to the second time point of data collection: The ratings showed that the overall impression of the post-CAMs was more ambivalent and neutral. The network analyses confirmed this impression as the post-CAMs contain on average more neutral and ambivalent nodes than the pre-CAMs. One explanation for the change toward more neutrality and ambivalence could be the exposure to topics of ethics of nature in the seminar, which might have changed the students' initial attitudes toward the topic and thus might confirm our research question 2b). Since the philosophical-ethical articles discussed the topics in a less judgmental manner, this may have changed the students' perspectives in the observed direction. Among the abundant research on attitude change through information, most focus is put on the effect of persuasion (Richardson et al., 2017), implying a specific direction of attitude change, usually toward (dis)agreement. However, the students in our study were not to be persuaded of a specific position – rather, they were encouraged to engage with heterogeneous positions. Studies in ambivalence research show that being embedded in a heterogeneous environment (for example, talking to oppositional political camps) is associated with more ambivalent political attitudes (Huckfeldt et al., 2004). Furthermore, Rudolph (2011) analyzed ambivalence as a dynamic experience and found that heterogeneous information increased individual attitudinal ambivalence. In addition to ambivalent nodes, there was also an increase in neutral nodes. In contrast to ambivalence as an activation of positive and negative impressions, affective neutrality is used to describe the absence of positive and negative affect. Taken together with the significant decrease in negative nodes we presume that previously negative affect was neutralized by engagement with the topic. The decrease of negative nodes and increase of mean valence corresponds with the raters' impression that the post-CAMs were more positive. Overall, according to the raters and network parameters, the post-CAMs seem to be more neutral, ambivalent and more positive.

Moreover, the post-CAMs contain slightly more ethical principles than the pre-CAMs. In addition, in the post-CAMs we could detect explicitly mentioned ethical principles, while the pre-CAMs only contained implicitly stated ethical principles. The wording of ethical principles is also likely related to what was learned in the ethics seminar since the wording strongly resembles the ethical principles of Krebs (2016b) and Muraca (2010). Please note that the analyses regarding ethical principles was restricted to these principles that were taught in the ethics seminar. We conjecture that the list of ethical principles derived from Krebs (2016b) and Muraca (2010) contains the most important principles, yet, other ethical principles would have remained unconsidered in the evaluation, even if they had been named by the students in the CAMs. Within this regard it is noteworthy that the work of Krebs (2016b) represents a summary and discussion of the principles from the ethics of nature found in the literature on the ethics of nature. Thus, it seems is unlikely that other ethical principles beyond the ethics of nature and sustainability would be named by the students. Indeed, the instructional text and the sample of nature imitation in technology development underlying our study deliberately focuses on problems of the ethics of nature and sustainability. Moreover, even when creating the pre-CAMs, the students already had in mind that they were creating them in the context of a seminar that focuses on the ethics of nature and sustainability. Finally, the principles for the ethics of nature given by Krebs were slightly extended by certain principles of the ethics of sustainability according to Muraca (2010). And this was done just after a first review of the ethical principles given in the CAMs (cf. in detail above chap. 3.2.1.). Methodologically, we followed the approach of the hermeneutic circle (cf. below chap. 5.3.).

5.2. Reflection of the methods Hypotheses vs. Hermeneutics

The present work tries to unite two scientific disciplines, psychology and ethics, taken as a subfield of philosophy. Through the interdisciplinary approach we see the potential for broadening perspectives and an emergent gain of knowledge. Interdisciplinary cooperation presupposes a disciplinary self-understanding (Eckardt, 2010) and is habitually confronted with difficulties, from differences in subject-specific terminology to methodologies to epistemological convictions (Möller et al., 2021). Philosophy and psychology share deep roots in the history of science. However, after psychology developed independently from philosophy at the end of the 20th century, the two scientific branches evolved as individual disciplines and today function largely independently of each other in research and teaching (Murray & Link, 2021). In this section, we reflect on our different research backgrounds and outline how we have dealt with them for this project.

The most popular conception of academic psychology portrays it as a science of describing, explaining, and predicting human experience and behavior. In its self-conception, psychology today sees itself primarily as an empirically oriented individual science (Eckardt, 2010). After paradigm shifts on the one hand and school formations on the other, different psychological tendencies coexist today, in terms of both epistemology and methodology. Academic psychology at German universities is generally considered to have a comparatively homogeneous self-image, in which it sees itself more clearly belonging to the natural sciences than to the humanities, since it conveys an understanding of science according to the falsification principle, in the sense of critical rationalism (Plischke, 2016). Thus empiricism plays a central role in academic psychology. Through qualitative and quantitative data collection and analysis, psychological models and theories are confirmed, further developed, or discarded.

Even if empirical research is gaining more and more importance in various fields of philosophy (e.g., ethics of artificial intelligence), a rather deductive (‘top down’) approach is predominant, especially regarding ethical questions.

Gaining knowledge is more likely to take place through reasoning and rationalism that is independent of empiricism. In the case of ethics, this rationalist rejection of empiricism has to do with the fact that its primary purpose is to formulate normative prescriptions for action. If, however, these prescriptions were derived from empiricism beforehand, this would result in an inadmissible circularity (Kant, 2019) or even a naturalistic fallacy, according to which one would conclude what ought to be from an actual state of affairs (Hume, 2011). It is true that applied ethics works empirically and takes data input from other sciences and societal contexts, but only the newer approach of empirical ethics, as already mentioned above (chap. 2), refers to empiricism and more precisely culturally specific, group-specific or even individual-specific attitudes as an essential part of ethical reflection and thus opens a more or less new paradigm.

Despite these different emphases, there are also overlaps in the objects of research and methods as well as mutual influence between psychology and philosophy or ethics, for example in the field of moral psychology. In the following, we reflect on the occasions in our collaboration where we noticed different approaches.

5.3. Hypotheses vs. Hermeneutics

In empirical psychological research, the research questions are first specified, then the methods are determined, the data are collected and analyzed based on the research question and the hypotheses that have been established. Hermeneutic approaches are rare and most likely to be found in qualitative psychological research. There are quality criteria and methodological standardizations for both quantitative and qualitative psychological research approaches.

In philosophy, on the other hand, there is no consensus on clear methodological guidelines for answering a research question (Reichling, 1996). Often, there is methodological agreement at best in the fact that the various philosophical approaches do not start from empirical data collection. One of the most influential attempts in the 20th century to justify the methods of the humanities and thus also of philosophy was undertaken by Gadamer (2006). In his view, the hermeneutic procedure of the humanities is characterized precisely by a positive circular structure, the ‘hermeneutic circle’. According to him, the understanding of a topic starts from a previous knowledge or ‘prejudice’ (*Vorurteil*) about the thing to be interpreted, which is essential in the process of understanding and at the same time must be constantly revised in the experience of a topic to be interpreted (Gadamer, 2006). Hermeneutics understood in this way does not simply operate in contrast to scientific research based on empirical data, which ideally proceeds inductively, ‘from the bottom up’. A hermeneutic understanding (of philosophy) does not proceed deductively, ‘from top to bottom’. Rather, it combines both approaches in a certain way, by confronting general patterns of understanding derived from a 'history of effects' (*Wirkungsgeschichte*) with concrete contexts to be interpreted, and bringing both into 'conversation' with each other.

Precisely because of this background, philosophy and ethics which proceed in a hermeneutic manner can be fruitful for the hypothesis-guided procedure of psychology in some scientific questions. In the context of the analyses of the CAMs drawn in the context of the ethics seminar (cf. chap. 3.2.), this can be seen in the two-fold evaluation of the CAMs by psychologists as well as philosophers, which seeks to interlock the two disciplines. While too much freedom for CAM drawers in the context of a hypothesis-guided evaluation by psychology can lead to raters producing overly subjective evaluation results, this is precisely where hermeneutic evaluative ethics can help. The 'hermeneutic circle' is applied here in a modified form in such a way that the raters exchange information with each other again and thus reduce their subjective 'prejudices' that flow into the evaluation. One could insert further 'circles' or 'loops of conversation' here, for example by discussing the results of the raters again with the CAM drawers themselves, whether they recognize their implicit positions in the evaluations or not. In this way, we complement the psychological approach, guided by empirical hypotheses, with the hermeneutic method stemming from philosophy and ethics. This gives rise to a form of empirical ethics which, on the one hand, is able to reflect culture-specific, group-specific or individual-specific attitudes and, on the other hand, is able

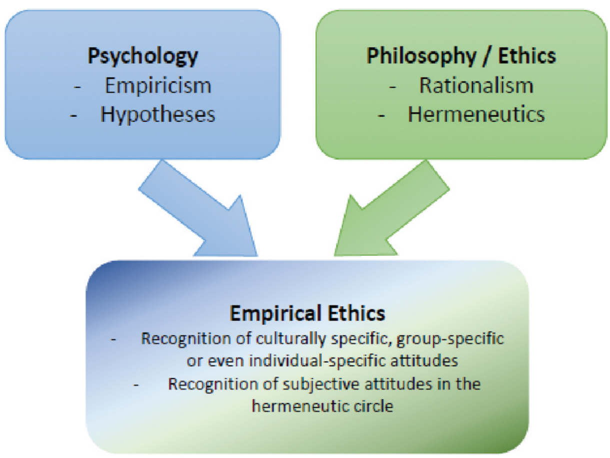

Figure 2. Sketch of constructive collaboration between psychology and philosophy/ethics in the context of empirical ethics. The empirical hypothesis-driven approach of psychology complements the methodology of philosophy/ethics through the recognition of culturally specific, group-specific or individual-specific attitudes. Hermeneutic philosophy/ethics complements the methodology of psychology by the methodological recognition of subjective attitudes in the hermeneutic circle.

to methodically deal with and recognize subjective attitudes by applying the hermeneutic circle, as Figure 2 shows.

6. Conclusion and outlook

We used CAMs as an empirical tool to detect changes in philosophy students' attitudes regarding bioinspired technologies and found that affective evaluation changed as well as the consideration of ethical principles. Our study within an ethics seminar showed that affective evaluations and, perhaps more interestingly, ethical evaluations were not stable variables. We assume that the learning content of the seminar contributed to students articulating ethical principles more explicitly in the second CAMs.

With this work, we aim to strengthen the collaboration between philosophy or more precisely ethics and empirical psychology to open new research perspectives. We see the unification of the different methodological approaches of both disciplines as a necessary challenge and broadening of perspectives. We have combined the empirical approach with a conceptual-normative approach, descriptive analyses and hermeneutic interpretations. We see CAMs as a suitable tool to combine philosophical or ethical and psychological approaches.

In this respect, we consider the procedure presented here as merely a first promising step in the context of an interdisciplinary collaboration between psychology and philosophy or ethics, which may lead to a form of empirical ethics. The increasingly rapid development of new technologies, and bioinspired technologies in particular, necessitates an ethical assessment that can keep pace with this 'Great Acceleration' (Steffen et al., 2015) and adequately incorporate the perspectives of all those who are and will be involved with these technologies as early as possible.

Notes

1. https://cam1.psychologie.uni-freiburg.de/users/loginpage?next=/.
2. (Krebs, 2016b) is a shortened German version of the English text by Krebs (1999), which, however, mentions the same principles of the ethics of nature.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC-2193/1 – 390951807. The work leading to this publication was also supported by the PRIME program of the German Academic Exchange Service (DAAD) with funds from the German Federal Ministry of Education and Research (BMBF).

Data Availability Statement

The Supplementary Material and the original data can be found on OSF: https://osf.io/brp9t/?view_only=9c98c736aee743baacfd5bb2a85af57c

Notes on contributors

Philipp Höfele is a philosophical researcher at the Freie Universität Berlin and a Visiting Scholar at Pennsylvania State University within the framework of the PRIME program, initiated by the German Academic Exchange Service (DAAD). He is specialized in the philosophy of nature and technology as well as practical philosophy and ethics with a historical focus on the philosophies of the 19th and 20th centuries.

Lisa Reuter is a psychological researcher who worked in the Cluster of Excellence Living, Adaptive and Energy-autonomous Materials Systems (livMatS) from 2019 to 2022 and continues to work at the Freiburg Institute for Basic Income Studies (FRIBIS). Through her work she explores possible applications for the method of Cognitive-Affective Mapping for psychological and interdisciplinary topics.

Louisa Estadieu is a doctoral research assistant in the Department of Philosophy of Freiburg, and an associate member of the Cluster of Excellence Living, Adaptive and Energy-autonomous Materials Systems (livMatS), University of Freiburg.

Sabrina Livanec is a doctoral researcher in the Cluster of Excellence Living, Adaptive and Energy-autonomous Materials Systems (livMatS) at the University of Freiburg. As her professional background is in developing and applying creative formats of mutual knowledge transfer between science and society, she explores Cognitive-Affective Mapping as a method to support communication processes in interdisciplinary and transdisciplinary settings.

Michael Stumpf is a senior research scientist in the Cognition, Action, and Sustainability unit at the Institute of Psychology, University of Freiburg. His research interests cover sustainability and technology acceptance, energy efficiency and energy saving, sustainable mobility, and scientific infrastructure.

Andrea Kiesel is full professor at the Institute of Psychology and head of the Cognition, Action and Sustainability unit, University of Freiburg. She is principal investigator in the Cluster of Excellence Living, Adaptive and Energy-autonomous Materials Systems (livMatS). Her areas of expertise are multitasking, action control, unconscious cognition, time perception and sustainability.

ORCID

Philipp Höfele http://orcid.org/0000-0002-8682-9965
Lisa Reuter http://orcid.org/0000-0002-2757-0498
Louisa Estadieu http://orcid.org/0000-0002-3164-4445

Sabrina Livanec http://orcid.org/0000-0003-3510-825X
Michael Stumpf http://orcid.org/0000-0003-1134-2930
Andrea Kiesel http://orcid.org/0000-0001-5564-010X

References

Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology*, *52*(1), 27–58. https://doi.org/10.1146/annurev.psych.52.1.27

Bem, D. J. (1967). Self-Perception: An alternative interpretation of cognitive dissonance phenomena. *Psychological Review*, *74*(3), 183–200. https://doi.org/10.1037/h0024835

Benyus, J. M. (2002). *Biomimicry*. Harper Collins.

Bessette, D. L., Mayer, L. A., Cwik, B., Vezér, M., Keller, K., Lempert, R. J., & Tuana, N. (2017). Building a values-informed mental model for New Orleans climate risk management. *Risk Analysis*, *37*(10), 1993–2004. https://doi.org/10.1111/risa.12743

Birnbacher, D. (1999). Ethics and social science: Which kind of co-operation? *Ethical Theory and Moral Practice*, *2*, 319–336. https://doi.org/10.1023/A:1009903815157

Eckardt, G. (2010). *Kernprobleme in der Geschichte der Psychologie*. Springer VS Verlag für Sozialwissenschaften.

Fabrigar, L. R., Petty, R. E., Smith, S. M., & Crites, S. L.,sJr. (2006). Understanding knowledge effects on attitude-behavior consistency: The role of relevance, complexity, and amount of knowledge. *Journal of Personality and Social Psychology*, *90*(4), 556–577. https://doi.org/10.1037/0022-3514.90.4.556

Fazio, R. H. (2007). Attitudes as object-evaluation associations of varying strength. *Social Cognition*, *25*(5), 603–637. https://doi.org/10.1521/soco.2007.25.5.603

Festinger, L. (1957). *A theory of cognitive dissonance*. Stanford University Press.

Findlay, S. D., & Thagard, P. (2014). Emotional change in international negotiation: Analyzing the Camp David accords using cognitive-affective maps. *Group Decision and Negotiation*, *23*(6), 1281–1300. https://doi.org/10.1007/s10726-011-9242-x

Gadamer, H.-G. (2006). *Truth and method*. Continuum.

Grunwald, A. (1999). Technology assessment or ethics of technology? Reflections on technology development between social sciences and philosophy. *Ethical Perspectives*, *6*(2), 170–182. https://doi.org/10.2143/EP.6.2.505355

Hart, W., Albarracín, D., Eagly, A. H., Brechan, I., Lindberg, M. J., & Merrill, L. (2009). Feeling validated versus being correct: A meta-analysis of selective exposure to information. *Psychological Bulletin*, *135*(4), 555–588. https://doi.org/10.1037/a0015701

Heider, F. (1958). *The psychology of interpersonal relations*. John Wiley & Sons Inc. https://doi.org/10.1037/10628-000

Höfele, P. (2022). Imitating nature through technology: On the question of an innovative and sustainable-ethical mimesis. Manuscript submitted for publication.

Homer Dixon, T., Maynard, J. L., Mildenberger, M., Milkoreit, M., Mock, S. J., Quilley, S., Schröder, T., & Thagard, P. (2013). A complex systems approach to the study of ideology: Cognitive-affective structures and the dynamics of belief systems. *Journal of Social and Political Psychology*, *1*(1), 337–364. https://doi.org/10.5964/JSPP.V1I1.36

Homer Dixon, T., Milkoreit, M., Mock, S. J., Schröder, T., & Thagard, P. (2014). The conceptual structure of social disputes: Cognitive-affective maps as a tool for conflict analysis and resolution. *Sage Open*, *4*(1), 2158244014526210. https://doi.org/10.1177/2158244014526210

Huckfeldt, R., Mendez, J. M., & Osborn, T. (2004). Disagreement, ambivalence, and engagement: The political consequences of heterogeneous networks. *Political Psychology*, *25*(1), 65–95. https://doi.org/10.1111/j.1467-9221.2004.00357.x

Hume, D. (2011). A treatise of human nature. In W. Editions (Ed.), *The essential philosophical works* (pp. 1–551). Wordsworth Editions.
Jonas, H. (1984). *The imperative of responsibility: In search of ethics for the technological age*. University of Chicago Press.
Kant, I. (2019). *Groundwork for the metaphysics of morals*. Oxford University Press.
Kibert, C. J. (2012). *Working Toward Sustainability: Ethical Decision-Making in a Technological World*. John Wiley & Sons.
Krebs, A. (1999). *Ethics of nature: A map*. Walter de Gruyter.
Krebs, A. (2016a). *Naturethik. Grundtexte der gegenwärtigen tier- und ökoethischen Diskussion*. Suhrkamp.
Krebs, A. (2016b). Naturethik im überblick. In A. Krebs (Ed.), *Naturethik. Grundtexte der gegenwärtigen tier- und ökoethischen Diskussion* (pp. 337–379). Suhrkamp.
Livanec, S., Stumpf, M., Reuter, L., Fenn, J., & Kiesel, A. (2022). Who's gonna use this? Acceptance prediction of emerging technologies with Cognitive-Affective Mapping and transdisciplinary considerations in the Anthropocene. *The Anthropocene Review*, *9*(2), 276–295. https://doi.org/10.1177/20530196221078924
Lorenz, J., Neumann, M., & Schröder, T. (2021). Individual attitude change and societal dynamics: Computational experiments with psychological theories. *Psychological Review*, *128*(4), 623–642. https://doi.org/10.1037/rev0000291
Luthardt, J., Schröder, T., Hildebrandt, F., & Bormann, I. (2020). "And then we'll just check if it suits us"—cognitive-affective maps of social innovation in early childhood education. *Frontiers in Education*, *5*(4), 1–19. https://doi.org/10.3389/feduc.2020.00033
Mansell, J., Mock, S., Rhea, C., Tecza, A., & Piereder, J. (2021). Measuring attitudes as a complex system: Structured thinking and support for the Canadian carbon tax. *Politics and the Life Sciences*, *40*(2), 179–201. https://doi.org/10.1017/pls.2021.16
Mayer, L. A., Loa, K., Cwik, B., Tuana, N., Keller, K., Gonnerman, C., Parker, A. M., & Lempert, R. J. (2017). Understanding scientists' computational modeling decisions about climate risk management strategies using values-informed mental models. *Global Environmental Change*, *42*, 107–116. https://doi.org/10.1016/j.gloenvcha.2016.12.007
Mayring, P. (2020). Qualitative Inhaltsanalyse. In G. Mey & K. Mruck (Eds.), *Handbuch qualitative Forschung in der Psychologie* (pp. 495–511). Springer. https://doi.org/10.1007/978-3-658-26887-9_52
Molewijk, B., Stiggelbout, A. M., Otten, W., Dupuis, H. M., & Kievit, J. (2004). Empirical data and moral theory. A plea for integrated empirical ethics. *Medicine, Health Care, and Philosophy*, *7*(1), 55–69. https://doi.org/10.1023/b:mhep.0000021848.75590.b0
Möller, M., Höfele, P., Kiesel, A., & Speck, O. (2020). Reactions of sciences to the Anthropocene: Highlighting inter- and transdisciplinary practices in biomimetics and sustainability research. *Elementa Science of the Anthropocene*, *9*(1), 1–16 https://doi.org/10.1525/elementa.2021.035
Möller, M., Höfele, P., Reuter, L., Tauber, F. J., & Grießhammer, R. (2021). How to assess technological developments in basic research? *TATuP - Zeitschrift Für Technikfolgenabschätzung in Theorie Und Praxis*, *30*(1), 56–62. https://doi.org/10.14512/tatup.30.1.56
Muraca, B. (2010). *Denken im Grenzgebiet. Prozessphilosophische Grundlagen einer Theorie starker Nachhaltigkeit*. Karl Alber.
Muraca, B. (2016). Relational values. A whiteheadian alternative for environmental philosophy and global environmental justice. *Balkan Journal of Philosophy*, *8*(1), 19–38. https://doi.org/10.5840/bjp2016813
Murray, D. J., & Link, S. W. (2021). *The creation of scientific psychology*. Routledge. https://doi.org/10.1002/jhbs.22113

Musschenga, A. W. (2005). Empirical ethics, context-sensitivity, and contextualism. *The Journal of Medicine and Philosophy*, *30*(5), 467–490. https://doi.org/10.1080/03605310500253030

Musschenga, B. A. W. (2009). Was ist empirische Ethik? *Ethik in der Medizin*, *21*(3), 187–199. https://doi.org/10.1007/s00481-009-0025-8

Paulo, N., & Bublitz, J. C. (2020). *Empirische Ethik. Grundlagentexte aus Psychologie und Philosophie*. Suhrkamp.

Pieper, A. (2007). *Einführung in die Ethik*. Francke Verlag.

Plischke, A. (2016). *Die akademische Psychologie unter der Lupe: Dissonanz zwischen studentischen Vorstellungen und wahrgenommener Studienrealität*. Springer Fachmedien. https://doi.org/10.1007/978-3-658-11178-6

Reichling, M. J. (1996). On the question of method in philosophical research. *Philosophy of Music Education Review*, *4*(2), 117–127. https://www.jstor.org/stable/40495423

Reuter, L., Fenn, J., Bilo, T. A., Schulz, M., Weyland, A. L., Kiesel, A., & Thomaschke, R. (2021). Leisure walks modulate the cognitive and affective representation of the corona pandemic: Employing Cognitive-Affective Maps (CAMs) within a randomized experimental design. *Applied Psychology: Health and Well-being*, *13*(4), 952–967. https://doi.org/10.1111/aphw.12283

Reuter, L., Mansell, J., Rhea, C., & Kiesel, A. (2022). Direct Assessment of Individual Connotation and Experience: An Introduction to Cognitive-Affective Mapping. *Politics and the Life Sciences*, *41*(1), 131–139. https://doi.org/10.1017/pls.2021.31

Rhea, C., Reuter, L., Tecza, A., & Mansell, J. (2021). Cam network analysis. https://doi.org/10.17605/OSF.IO/PXNVZ

Rhea, C., Reuter, L., Thibeault, C., & Piereder, J. (2021). Valence software release. https://doi.org/10.17605/OSF.IO/9TZA2

Richardson, K., Tortoriello, G. K., & Hart, W. (2017). Attitudes. In V. Zeigler-Hill & T. Shackelford (Eds). *Encyclopedia of Personality and Individual Differences*,Springer. https://doi.org/10.1007/978-3-319-28099-8_1777-1

Rudolph, T. J. (2011). The dynamics of ambivalence. *American Journal of Political Science*, *55*(3), 561–573. https://doi.org/10.1111/j.1540-5907.2010.00505.x

Schopenhauer, A. (2004). Über die Grundlage der Moral. In W. F. von Löhneysen (Ed.), *Sämtliche Werke* (pp. 727–744 & 802-813). Wissenschaftliche Buchgesellschaft

Scott, W. A. (1955). Reliability of content analysis: The case of nominal scale coding. *Public opinion quarterly*,*19*(3), 321–325.

Seel, N. M. (2012). Attitudes – Formation and Change. In N. M. Seel (Ed.), *Encyclopedia of the Sciences of Learning*. Springer, 371–374. https://doi.org/10.1007/978-1-4419-1428-6_359

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the Anthropocene: The Great Acceleration. *Anthropocene Review*, *2*(1), 81–98. https://doi.org/10.1177/2053019614564785

Thagard, P. (2006). *Hot thought. Mechanisms and applications of emotional cognition*. MIT Press. https://doi.org/10.7551/mitpress/3566.001.0001

Thagard, P. (2010). Empathica: A computer support system with visual representations for cognitive-affective mapping. In K. McGregor (Ed.), *Proceedings of the workshop on visual reasoning and representation*, Menlo Park, CA (pp. 79–81). AAAI Press.

Thagard, P. (2012). Values in science: Cognitive-affective maps. In P. Thagard, *The cognitive science of science: Explanation, discovery, and conceptual change* (pp. 283–302). MIT Press.

Thagard, P. (2015). Value maps in applied ethics. *Teaching Ethics*, *15*(1), 115–127. https://doi.org/10.5840/tej20151519

van Roojen, M. (2009). Moral cognitivism vs. non-cognitivism. *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/moral-cognitivism/

von Gleich, A., Pade, C., Petschow, U., & Pissarskoi, E. (2010). *Potentials and trends in biomimetics*. Springer. https://doi.org/10.1007/978-3-642-05246-0_2

Wason, P. C. (1960). On the failure to eliminate hypotheses in a conceptual task. *The Quarterly Journal of Experimental Psychology*, *12*(3), 129–140. https://doi.org/10.1080/17470216008416717

Wolfe, S. E. (2012). Water cognition and cognitive affective mapping: Identifying priority clusters within a Canadian water efficiency community. *Water Resources Management*, *26*(10), 2991–3004. https://doi.org/10.1007/s11269-012-0061-x

Appendix

Information Text about Nature Imitation in Technology Development

This text was translated into English – the original version in German can be found in the Supplementary Material 8.

The CAM should depict your thoughts and evaluations regarding the imitation of nature by technical products. Before doing so, please read a short text on this topic:

In our everyday life we often encounter things that are called ‘organic’ or ‘biological’. This does not only mean food from ecologically sustainable cultivation, i.e., GMO-free natural products. Cosmetics, clothing, garbage bags, cleaning agents, building materials, fuels or electricity are also referred to as ‘bio(logical)’ or ‘ecological’, i.e., technical products which are of artificial origin and which are ascribed a closeness to nature by means of this ‘label’.

However, technical products are not usually perceived as natural or nature-like, i.e., they are distinguished from plants, animals and other natural entities. The distinction is based on the fact that technical products, unlike natural ones, are, for example, manufactured and consist of materials that do not occur in nature and are therefore artificial.

At the same time, in view of environmental problems, we are placing more and more emphasis on sustainable technologies. Sustainability is to be ensured, for example, by the use of regenerative and non-hazardous materials or the degradability of broken and discarded technical products, so that the environment is not adversely affected to the detriment of present and future human and non-human life. In a normative sense, it is precisely such technologies that are described as future-proof and good.

This is accompanied by an increasing preference for technical products that imitate nature and are thus similar to nature. This imitation of nature does not refer so much to the appearance of the technical products, but rather to the use of nature-like materials or the imitation of mechanisms found in nature.

Outline your thoughts, arguments, and evaluations regarding the imitation of nature by engineered products as explained in the instructions.