Art and Higher Education for Environmental Sustainability

A matter of emergence?

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Art and Higher Education for Environmental Sustainability: A matter of emergence?

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Abstract

Purpose—This study aims to contribute to the exploration of inter-disciplinary approaches in higher education for sustainability. It is a reflection on a case study linking students in the arts and sustainability science, through which the inter-disciplinary and problem-solving processes for solving a concrete sustainability challenge were explored.

Design/methodology/approach—The case study featured a workshop with students from two educational programmes at Aalborg University: Art and Technology (ArT) and Environmental Management and Sustainability Science (EMSS), the latter being an engineering programme and the former part of the humanities. Experience evaluation was based on participant observation, written feedback, and the workshop facilitators' post-event reflections. Data analysis was based on multi-grounded theory, dialectically combining empirical data (through open coding) with relevant emergence theories. Notions of emergence were chosen because the supposed benefit of inter-disciplinarity is the emergence of novel solutions to complex problems. Our study investigates the concrete conditions of emergence in educational inter-disciplinary settings.

Findings—The workshop led to a successful experience, bringing an art-based approach together with sustainability science for arriving at solutions that neither of the two would have arrived at separately. Based on participant experiences and realisations, five 'emergence concepts' are suggested as supportive learning criteria and conditions: 'knowledge expansion', 'complementarity', 'disciplinary self-reflection', 'change of practice', and 'play'.

Originality—The findings and emergence concepts can be inspiration for creating an effective learning environment supporting the emergence of different forms of knowledge and solution concepts for solving sustainability challenges.

Keywords: Art, sustainability, emergence, problem-based learning, higher education, inter-disciplinarity

1. Introduction and background

This study aims to contribute to the exploration of inter-disciplinary approaches in higher education for sustainability. The paper is a reflection on a case study linking students in the arts and sustainability science, through which the authors explored the inter-disciplinary and problem-solving processes used to solve a concrete sustainability challenge. The introduction first presents the challenges for sustainability science and the relevant aspects of art as background, followed by the research questions and the notion of emergence as relevant for this study. Next, the concrete context and the applied empirical methods are presented, followed by the analysis of the empirical material. Finally, a discussion and conclusion are presented.

1.1 Sustainability and sustainability science

Within the field of sustainability science, critical voices are questioning the fact-based and linear discourse of their research, arguing that all environmental solutions include human agents, be they politicians and law makers or citizens who have to accept, understand, and apply new values and procedures that support environmental sustainability. The sustainability science, which is an integrated and place-based science, '…seeks to understand the fundamental character of interactions between nature and society and to encourage those interactions along more sustainable trajectories' (Kates *et al*., 2001, p.641). As argued by Fischer *et al.* (2012), it is not the lack of knowledge that hinders sustainability – it is rather the acting on existing knowledge, which also requires recognition of the strong influence of value and belief systems. Humans are evolution-based biological, historical, and socio-cultural beings who embody and engender habits and values that can hinder the effectuation and application of scientific findings regarding environmental sustainability. An element of this is the psychological and affective aspects that play a major role in a change towards sustainability (Koger and Winter, 2010; Kals *et al*., 1999; Damasio, 2006). Based on the recognition of the emotional aspects of human behaviour, also regarding sustainability, Shrivastava *et al*. argue for the need to link passion and emotion with the sustainability discourse – and that the link can be nurtured through art:

> No great human endeavour has ever been accomplished without passion. Passion is the key to great accomplishments. Passion is therefore central to achieving the great feat of sustainability. In this pursuit, science and technology are important contributions but by themselves they are insufficient. It is important to go beyond science and consider ways of infusing passion into the pursuit of sustainability. Arts are a vehicle of human emotions and passion. (Shrivastava *et al*., 2012, p.25)

For example, research exploring art 'as a vehicle' has found that arts affect pro-environmental belief, values, and attitudes (e.g. Curtis *et al*., 2014; Marks *et al*., 2016), can catalyse and help community involvement in sustainability (e.g. Mrill, 2012; Curtis *et al*., 2014; Connelly *et al*., 2016), and help creativity and the concrete solving of sustainability challenges (e.g. Connelly *et al*., 2016; Lopes *et al*., 2017).

Furthermore, within the context of education for sustainability, the aesthetic approach with explicit links between science and art seems to hold potential. Clark and Button (2011), for example, explore the application of the sustainability transdisciplinary education model, in which converging science, art, and aesthetics proves valuable for expanding the understanding of sustainability and the human impact. In the context of teacher education for sustainability, Gedzune and Gedzune (2015) activate presentational knowledge through aesthetic learning. One finding is that participants

> …who appear to value the richness of visual and aesthetic language that enables communication of complex ideas, highlight its power of leading to personally meaningful and practical insights and commend its contribution to their building emotional bonds with their peers in a sensitive and nurturing atmosphere. (p.90)

In particular, within a higher educational context, which is the focus of the present study, Sipos *et al*. (2008) integrate cognitive, psychomotor, and affective domains in their transformative sustainability learning. Their findings suggest that transformative sustainability is supported by integrating 'transdisciplinary study (head); practical skill sharing and development (hands); and translation of passion and values into behaviour (heart)' (2008, p.68). In line with this, Shrivastava (2010) explores the holistic pedagogy integrating cognitive learning about sustainability with physical and emotional learning and finds the development of emotional learning and passion. In particular, within the fields of science, technology, engineering, and mathematics, Root-Bernstein (2015) finds that arts foster scientific creativity, which is central for perceiving and imagining solutions to complex sustainability challenges. Exploring the synergies between chemistry and art through cross-disciplinary course teaching, Marteel-Parrish and Harvey refer to system thinking allowing "..the students to analyse the connections between chemical, ecological, and human system.." and finds how it transform both fields. (2019, p. 148)

Despite the commonly agreed potentials for art-science integration in educations as a mean to facilitate collaborative sustainability, the literature regarding empirical evidence and efficacy is still limited (Herro et al., 2018; Quigly et al., 2019; Trott et al., 2020). This paper contributes with an empirical case within the context of higher education.

1.2 Art, science, and sustainability

Artistic endeavours are most often thought of as confined to cultural institutions and the so-called art market. Many artworks deal with important societal themes (such as sustainability) and create experience spaces that question existing values, mechanisms, and ways of thinking and acting. However, this freedom of expression and creation is constrained based on the societal distinction between art and other societal fields, including research. Several avant-garde art movements have tried to tear down this cultural divide, each with their own means and purposes. Unfortunately, art institutions and the art market, along with their inherent mechanisms, have proven to be able to incorporate all these avant-garde attempts and thus annul their socio-political impetus.

Another attempt to counteract art's confinement is the art and science movement and several educational programmes that consider artistic approaches as valuable aspects of academic research, in that they can contribute to problem-elaboration and solution-finding processes – especially in the field of citizen participation and inclusion but also in other fields such as data visualisation and concept and product development. Poietic creations and aesthetic experiences may harbour both affective, emotional, reflective, and meaning-instigating dimensions (e.g. Markovic, 2012; Wilson, 2002; Morton, 2010) that can prove valuable for a change towards a more sustainable future.

Both art and engineering work towards the creation of novel artefacts (works of art or technical solutions, respectively) that are based on creative ideation and emergence. On the face of it, their methodologies are very different; art mostly relies on analogical, associative thinking and affective experiencing during creation, whereas science is based on different forms of reasoning (deduction, induction, and sometimes abduction). However, as Koestler (1977) has proposed, both the discoveries in science and the convincing creations in art are based on the tension between different conceptual fields (matrices) to transcend the dominant field's inherent discourse. Many scientific theories on creativity exist; most of them are based on the idea of a surprising yet prepared leap yielding new concepts or inventions (e.g. Koestler, 1977; Amabile, 1996; Sternberg, 2011; Csíkszentmihályi, 2013). Artistic processes of creation seem to be able to accommodate the identified lack of affective and emotional aspects in sustainability science.

On addition to these basic scientific texts on art and creativity, there is a growing body of artworks and texts on various forms of collaboration between art and science and art and engineering. There are also many artistic and curatorial projects dealing with sustainability and climate change, and there are academic texts on the subject such as Kagan (2011) and Lineberry and Wiek (2016)). Furthermore, art and art making play a role in pedagogy theory and practice: Eisner is one of the most prominent and earliest scholars in the field (Eisner, 1981). However, to the best of our knowledge there have been no classroom experiments within higher education which, on a didactical basis, brought together art and engineering students, and which have been described in the public domain.

2. Research questions

The background for the case study is a one-day workshop conducted at Aalborg University in April 2018. Nineteen students of two different educational programmes ('Environmental Management and Sustainability Science (EMSS)' and 'Art and Technology (ArT)') were recruited by their respective professors (the authors of this article) to be part of this workshop. The primary pedagogical aim of the workshop was to further inter-disciplinary concept development in the context of a very concrete and palpable sustainability challenge: 'How can we approach the problem of 30 tons of non-recyclable PVC airbeds left by the audience of a week-long music festival in Denmark'?

The intended inter-disciplinary approach reflects Boden's concept of 'co-operative inter-disciplinarity', which requires collaboration and teamwork to tackle a complex problem by going beyond the sequencing and coordination of disciplines (Boden, 1999; Klein, 2017). Our assumption was that when an art-based approach is brought together with sustainability science, there will be a basis for arriving at solutions that neither of the two approaches would have arrived at separately. In other words, the two approaches can produce an emergent solution. The secondary, underlying objective of the workshop was to conduct academic and practical research into the educational requirements for diachronic emergence. Our own experiences during the workshop and the incipient analysis of the empirical data made us slightly shift focus from the creation of emergent solutions towards the conditions for emergence. The secondary objective became more pertinent. The choice of theory describing the concept of emergence (in the following section) supports this analytical objective by adding Deleuze's take on difference as a condition for potentiality and emergence.

The subsequent analysis of results was performed based on the following explorative research questions:

1. What are the important participant experiences and realisations that support an inter-disciplinary educational workshop?

2. How then can we orchestrate such a workshop that supports emergent solutions (concepts) to a distinct environmental challenge?

From the outset, emergent solutions are defined as solutions that cannot be brought about by one discipline only but that necessitate at least two unique disciplinary approaches – in our case, an artistic approach and an engineering approach, or more precisely, sustainability science.

Hence, this study intends to map some of the inherent effects and dimensions of the process of emergence of non-anticipatable solution concepts in an inter-disciplinary educational context. This is done by empirical research, specifically by analysing the content of a questionnaire filled out by the students immediately after the workshop. The authors will describe in depth the participating educational programmes, the workshop setting, and the method applied in later sections. First, the authors introduce the notion of emergence as a relevant framework for our investigation. This serves as a theoretical background and foundation for our analysis of the empirical data.

3. Emergence

The following is a short presentation of the key concepts of emergence and synergy as relevant for our investigation.

Emergence is defined as the creation of a higher-level system or entity on the basis of lower-level systems or components. The emergent entity or system and its properties must not be deducible from the interacting lower levels. Philosophy of science distinguishes between nominal, weak, and strong emergence (Bedau, 1997, p.158). Strong emergent systems necessitate a complete reformulation of scientific concepts owing to the emergent phenomena. According to Chalmers (2006), only one case of strong emergence is known: that of consciousness. Consciousness is seen as the emergent result of brain activities; consciousness cannot be understood on a material level as bio-chemically defined occurrences, although it depends on these occurrences. Consciousness is correlated and supervenient to those bio-chemical activities but cannot be comprehended in those terms. Most cases of emergence are classified as weak emergence, where the characteristics of emergent entities or systems in principle are deducible but, in reality, are surprising. 'We can say that a high-level phenomenon is *weakly* emergent with respect to a low-level domain when the high-level phenomenon arises from the low-level domain, but truths concerning that phenomenon are *unexpected* given the principles governing the low-level domain' (Chalmers, 2006, p.244). Weak emergence is seen as a subset of nominal emergence, which is the most basic definition of emergence: 'The simplest and barest notion of an emergent property, which I term mere nominal emergence, is simply this notion of a macro property that is the kind of property that cannot be a micro property' (Bedau, 1997, p.158). One example is the circularity of a circle conceptually composed of multiple squared dots.

Emergence is furthermore characterised by downwards causation (Campell, 1974), where emergent phenomena or properties have a decisive effect on the lower-level phenomena. This proposition is extensively discussed in the literature. Chalmers (2006) asserts that strong or weak emergence can have either a weak or strong downwards causation. Theoretically, strong emergence and weak downwards causation result in an epiphenomenon, whereas weak emergence and strong downwards causation are typically found in emergent systems in which procedures and structures govern the low-level constituents.

From this very brief introduction, it seems clear that our application of the concept of emergence must, if at all, be of the weak kind. The resulting phenomena in our application – that is, solution concepts to the posed problem of 30 tons of PVC – in principle could be deduced but in reality are unknown at the time of the workshop planning and at the time of the inter-disciplinary groups' discussions that eventually did lead to solution proposals. The trick inherent in the conceptualisations of emergence is that emergent phenomena can only be known *post factum*, after the emergence has occurred.

This unanticipated *something* is envisioned as a phenomenon that is dependent yet different from the participating constituents. Bedau (1997) writes: 'We can provide some order to this controversy by distinguishing two hallmarks of how macro-level emergent phenomena are related to their micro-level bases: (1) Emergent phenomena are dependent on underlying processes. (2) Emergent phenomena are autonomous from underlying processes'. In our case, the emergent concepts are, of course, dependent on the participating persons and their educational background, including the application of various methodological discourses as well as each participant's unique knowledge and aptness to relate to other workshop participants and their personal ways of finding solutions together. The emergent solution concepts cannot be deduced from either the participants' unique programmatic (scientific or artistic) knowledge and methodology or their personal profile. Nevertheless, aspiring to Bedau's second hallmark, the emergent solution concepts should be autonomous in that they should present other kinds of concepts that are neither (only) engineering/technical solutions nor (only) artistic/elaborative creations. Moreover, the solution concepts should be communicable and hopefully be able to be worked on by other people and initiated as concrete solutions that in turn can reach or influence many other people.

The definitions of emergence (coming from system science) introduced above begin with the identification of emergent phenomena. These theories establish a distinct relationship between the emergent level and its processual constituents *post factum*. However, the objective of our investigation turned out to be rather the opposite. The authors aimed to explore the beneficiary conditions for the potential emergence of novel solution concepts that neither the arts nor engineering could have brought about separately. In our daily jargon, the authors talked about a third space as a metaphor for a productive realm that is brought about by a creative nexus of differences between scientific and artistic approaches. The workshop planning can only intend to create a processual and conceptual framework comprising simple rules and settings that hopefully accommodate the emergence of *something* not yet known. According to Protevi (2006, p.20), who writes on Deleuze and Guattari's notion of emergence, this would be diachronic emergence or creative evolution.

The most fundamental condition for this kind of emergent concept is difference. Inter-disciplinarity works with difference. Students of different educational programmes try to create concepts together. On a more basic level, different people intend to bring about solution concepts. Different methodologies, an artistic and a scientific one, meet in a workshop setting. The notion of difference is fairly brought about and has many philosophical significances and nuances. It is used as the antidote to identity, defined by Leibnitz (Noonan & Curtis, 2018) as entities that share the same properties. The notion of difference has gained much importance, especially for structuralism and post-structuralism, which are built upon various dynamics difference yields. Deleuze, a distinct representative of post-structuralism, builds his entire understanding of emergence upon an ontology of difference. One key concept is heterogeneity, the simultaneity of immanent, differential constituents. Differential heterogenic constituents – be they particles, already formed systems of any kind, ideas, or events – create tensions (attraction and repulsion) and thus a dynamic, or more precisely, the dynamic of becoming. Deleuze's main idea is that differentials constitute the most fundamental ontology that is the *sine qua non* for, for example, representational identities (such as substances). Differentiations create instabilities in existing systems that need to be solved by finding new actions and new structures. New structures can only be actualised on the basis of 'virtual multiplicities' (Deleuze, 1988, p.80). Virtual multiplicities are not yet formulated 'Ideas': 'An Idea, in this sense, is […] a multiplicity constituted of differential elements, differential relations between those elements [….]' (Deleuze, 1994, p.278). In other words, difference creates a realm of potentiality prior to the formation of representations. Situations of potentiality are unstable and must be resolved by actualisations. Diachronic emergence is one effect of this ongoing differentiation process.

By now, it should be clear that neither did the authors' analysis focus on the concrete emergent concepts produced during the workshop – they will, however, present some concrete examples thereof – nor did they want to find empirical data to validate one distinct concept of emergence. Rather, they were interested in the synergetic[1] effects of this kind of collaboration between different persons with different educational backgrounds. During the workshop and the analysis, the authors discovered that difference is the driving force of synergy and thus emergence. In our application of Deleuze's ontological notion, inherent difference is simply seen as concrete differences at several levels, ranging from personal to methodological and epistemological differences. Consequently, the synergetic effects are personal and experiential, as expressed in the participants' immediate responses to the workshop. They tell us about what aspects of interpersonal and inter-disciplinary work were experienced as important for collaborative and creative work that supports and sustains emergent solution concepts. Our workshop and analysis were based on the question of which synergetic conditions are beneficial for emergent solution concepts. Therefore, the purpose of bringing together students of the two programmes was the anticipated emergence of a different form of knowledge – or better realisation – than either art or science can independently yield. The envisioned novel form of realisation should be concretised and represented by solution concepts that amalgamate artistic and scientific qualities into altered or expanded ways of thinking and acting.

4. The setting: Different academic disciplines, same university pedagogy – problem-based learning

The two educational programmes were ArT and EMSS, the latter being an engineering programme integrating STEM (Science, Technology, Engineering, Mathematics) and sustainability and the former part of the humanities. Both are inter-disciplinary programmes: ArT works with both artistic and academic methods and EMSS works with methods from engineering and social sciences.

ArT students learn to develop their artistic competences by creating various forms of artefacts such as sculptures and interactive installations and through participatory events or performances using (mainly digital) technologies and applying theories from the humanities (aesthetics, art theory, media studies, and culture) and sociology (social systems). ArT at Aalborg University is decisively practice-based in that the development of artistic artefacts propels the retrieval of knowledge and skills.

EMSS students work with real-world sustainability problems through problem-based learning and in close contact with societal stakeholders. They learn to define and solve environmental and sustainability-related problems; get hands-on experience with a range of techniques such as environmental planning, environmental management and assessment, eco-design, and climate mitigation and action; and get competences to understand the social and institutional context of decision-making and behaviour for sustainability.

All educational programmes at Aalborg University are based on 'The Aalborg Model' of problem-based learning pedagogy (Aalborg University, 2015; Holgaard *et al.*, 2014; Kolmos et al., 2004; Qvist, 2004), including the two programmes involved in the case study. Most semesters of both undergraduate and post-graduate levels include at least one big project, where students acquire knowledge and competences by choosing and tackling academic problems within their specific area of study. Most often, students work in groups for choosing and formulating their own academic problem, designing their own research approach, choosing and applying relevant methods, and describing their finding in the form of a report. This process typically includes the retrieval of empirical data (if required), application of theories, sharing of knowledge through discussions and joint reflections, and writing of the project report. However, the type of problems and their concrete formulations and elaborations significantly vary between the educational programmes and their specific discipline and research traditions. On one hand , the authors find purely theoretical problems (e.g. philosophy); on the other hand, students work with very concrete societal or technological challenges often in collaboration with external partners such as municipalities, private companies, or other interested organisations. Moreover, each programme defines the degree of liberty regarding the students' choice of problem field and the project formulation. Some studies have a fairly tight thematic and methodical framework, whereas other studies depend much more on the students' aspirations to explore practical and conceptual fields within the confines of their academic discipline.

5. Methodology

In this section, the context in which the empirical data were gathered as part of the workshop is described. In addition, the methodology for data collection and the analysis of data are described.

5.1. The experiment and workshop

The one-day workshop was thematically centred on a specific societal challenge: 'How can we approach the problem of 30 tons of non-recyclable daybeds (PVC) left by the audience of a week-long music festival in Denmark'? Each year, the participants of Roskilde Festival in Denmark leave approximately 30 tons of worn-out airbeds that cannot be recycled, which are currently disposed of in landfills. The removal of such a large amount of PVC is extremely costly. The use of non-recyclable PVC raises the question of whether the habits and knowledgeability of the majority of festival visitors are suitable in light of this environmental problem.

The workshop involved four parts:

I. Presentation, in which the workshop participants were introduced to the main objective, the methodological and discursive differences between arts-informed research and sustainability science research, and the concrete challenge at hand.

II. Concept development in mixed groups of approximately four students. For the concept development, the participants were asked to follow two dogmas: (1) DNA from each discipline will be included and should be visible in the developed concept/solution and (2) synergism in concept (solution) must be explained. Synergism was presented as related to 'the interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects' (Oxford Dictionary).
III. Presentation of concepts in plenary.
IV. Evaluation session in which the participants individually answered two open-ended questions.

The main part of the workshop comprised the mixed group work among 19 students from the ArT programme and 18 students from the EMSS programme. The authors implemented a rather general workshop structure, allocating a considerable amount of time for the groups to develop their specific way of collaboration and solution-finding processes.

5.2. Data collection

The empirical data depict information collected from the workshop evaluation. Each participant responded in writing to two open-ended, fairly simple questions:

1. Has anything about the collaboration today surprised you, also in relation to your expectations?
2. What will you take away from today's experience?

In addition to their answers, they noted their gender and educational programme. All answers, in their complete text, were collected in a separate document for coding. The data collected from the students contained 87 statements in Danish.

Both facilitators also collected information through unstructured observations during the entire workshop. The observations, some of which were written in the form of field notes, provided informal feedback about the groups' processes, including the deliberate or evolving structure of their process; the misunderstandings, difficulties, and breakthroughs; and the overall atmosphere of the entire workshop and the individual groups during their discussions and concept development processes and during the presentation. The observations were not used in the analysis of participants' statements but provided the contextual understanding of the cooperation between the two disciplines.

Note that the presented solution concepts at the end of workshop – especially the degree of how convincing they were to us and what the convincing elements were – evidently tainted our analysis of the data. All the presented concept solutions were events or artefacts to be mounted, presented, or initiated at the festival site and contained an ambition to engage and affect the public towards more sustainable behaviour. Most of the solutions comprised more or less intricate and integrated aspects of scientific facts about PVC and aesthetic experiences that directly addressed affective, associative, and bodily dimensions.

The most intriguing concept produced was the idea of a circularly arranged graveyard somewhere in the festival area comprising a small number of graves. The graves would be covered with glass plates showing the airbeds in open coffins. The inscription would show the date of birth and death of the airbeds (often having only several days of use) and the expected decomposition time (which is almost infinite; European Commission, 2000). As such, the idea is rather simple, yet it brings both scientific and artistic dimensions into an oscillating interplay. In the analysis section of this article, the authors will use this example to elucidate the experiential conditions of emergence.

5.3. Coding and analysis

The 87 statements from the students were analysed through open coding, which can be described as 'the interpretive process by which data are broken down analytically. Its purpose is to give the analyst new insights by breaking through standard ways of thinking about or interpreting phenomena reflected in the data' (Corbin and Strauss, 1990, p.12). This qualitative and systematic process of content analysis is aimed at recognising and conceptualising the issues of importance and interest in relation to the intended emergence of a different form of knowledge, based solely in neither art nor science, and the experiential factors that potentially sustain emergence.

The coding involved 'initial coding' and 'notions'. The initial coding was performed statement by statement and was closely related to the data, not involving priori codes. As underlined by Charmaz (2006), 'the initial codes are provisional, comparative, and grounded in the data' (p.48).

The labelling of the notions represents the next stage with focused coding to 'synthesize and explain larger segments of data' (Charmaz, 2006, p.57). In this stage, the codes are more selective and conceptual than in the sentence-by-sentence coding stage and the two researchers acted upon the data. During this process, several codes were generated by the authors in a joint iterative reflective process. The initial coding was inductive, after which the theoretical framework on 'emergence' gave inspiration to some of the notions.

To illustrate the coding, Table I presents a section of the entire coding process of the data. A full version of the data and analysis can be found in the supplementary materials to the article.

Table I. An illustration of the coding of data from students' statements.

Raw data (students' statements)	Initial coding	Notions
I have also learned that art is about giving or triggering experiences in people.	Learned about the role of art for human experiences	Knowledge expansion
The EMSS students were feeling like the pessimistic party, shooting down ideas that weren't sustainable.	Experienced difference in approaches to problem-solving	Complementarity
EMSS thinks long-term and ArT thinks short-term.	Experienced difference in approaches to problem-solving	Complementarity
Inspiring. Nice to co-work.	Inspired by co-working.	Complementarity; Knowledge expansion
We learned our own stuff more through explaining it to others.	Learned own discipline by explaining to others	Disciplinary self-reflection

The day was very relaxed and pleasant – no pressure.	Liked the collaboration being relaxed – without pressure	Play
Interesting working with cross-disciplinary folk and working with different points of view.	Liked inter-disciplinary work involving different points of view	Complementarity
I live for the creative process and it was a wonderful experience seeing things in a different light.	Liked the experience of seeing things in a different light	Play; Knowledge expansion

The analysis presented in this paper is not only based on the empirical data represented in the students' statements. Besides the inductive coding and analysis of statements, the paper is also grounded in the theoretical framework of 'emergence' presented in section 2. The methodology therefore does not follow the strict induction in the orthodox form of grounded theory because the grounding means both empirical grounding and theoretical grounding, in which the data are reflected against the conceptualisation of emergence. The approach is that of multi-grounded theory as proposed by Guldkuhl (2003) and Cronholm (2010) – dialectically combining empirical data and pre-existing theories in a synthesis.

6. Results: Five main 'emergence notions' identified

The purpose of the current study was to explore the evaluative experiences of the participating students in the inter-disciplinary work across engineering and arts to find solutions to a societal sustainability challenge in a problem-based learning university setting. A central aim was to gain insights into the workshop's effects on each participant that potentially support the emergence of a different form of knowledge and a different form of solution concepts.

This section describes the data stemming from observations and from codes and notions. Focus is on the overarching themes that emerged from the data.

The evaluation data led to a sample of 87 written opinions, which turned into 5 core notions as presented in Table II (experiential aspects). Except for one answer, all answers reflected either a neutral or positive attitude towards the experience and the outcome of the workshop. Our selection of notions was guided by our ambition for the emergence of different kinds of solution concepts for sustainability – solutions that simultaneously address people at multiple levels, can potentially create epistemological and affective relations between scientific facts, technical solutions, and emotional and bodily experiences, and can create an effective learning environment for emergence.

Table II. Emergence concepts.

Core notions	Knowledge expansion	Complementarity	Disciplinary self-reflection	Change of practice	Play
Incidents	36	24	9	6	4

The following is an elaboration of our selected notions. The underlying strategy is to combine the students' commentaries with characteristics of emergence to specify positive and supportive learning criteria and conditions. In the following sections, students' written commentaries in the form of quotations are used to illustrate the nature of the five notions. As the answers to the open-ended questions was anonymous, the students only explicated whether they were arts or engineering students, and therefore reference is made only to 'ArT students' or 'EMSS students'. In a few cases, students' responses have not included a clarification of which study they belong to. In these cases, the reference 'Unknown' is used.

6.1. Knowledge expansion

Knowledge expansion seems to have taken place for both groups of students. The EMSS students especially underline the obtained knowledge of art and the inherent possibilities of applying artistic approaches in the work. The expansion is, for example, expressed through the acquired knowledge of possible roles of art: The workshop '*…helped to open my mind towards art and help me to understand concepts in a different way*' (EMSS student) and '*…see a different way of understanding the concept of art*' (EMSS student). The communicative and affective role of art was also understood as illustrated by students who '*…gained some understanding of how art can convey messages relating to real world issues*' (EMSS student) and '*…learned that art is about giving or triggering experiences in people*' (EMSS student). Both students are hereby underlining the affective and psychomotor aspects of solution concepts.

Further, EMSS students experienced the way ArT students '*are more tangible in the way they create solutions*' (EMSS student) and recognise the qualities in a different outset for work being '*… a reminder of how we sustainability students often tread the exact same paths in our work and that one can start from a complete different outset. Good experience - keep it!*' EMSS student). One student also recognise that it inspires future practice '*being "crazier" and not to be afraid of the "unrealistic" ideas. Use them as a starting point*' (EMSS student).

ArT students highlight other issues than the EMSS students, including bringing more 'reality' and feasibility into the work and solutions because '*…it helps us to see and experience how the real world will be, when we are done*' (ArT student). Besides pointing at expanded knowledge of concrete concepts such as '*the scientific/actual background or problem behind a project and also the knowing of PVC*' (ArT student) and '*the hierarchy of sustainability*' (ArT student), students especially emphasise practical reasoning which for some was an unexpected lesson: '*I learned more about the process of practical reasoning*' (ArT student), and '*I learned much about practical reasoning and context-based realizations or actualizations*' (ArT student).

Overall, the students expanded their understanding of inter-disciplinary collaboration, and several indicated a productive reflection on prejudices in this regard: '*I was surprised how different our approaches were academically and how we actually were able to combine these two approaches into shared ideas. I expected them to clash more negatively*' (ArT student) and the surprise of '*how easily the two fields actually worked together, and how easy it was to communicate ideas and possible solutions*' (ArT student).

Knowledge expansion clearly is a result of experienced differences between the known and something unknown that subsequently comes into the focus of attention. The experience of knowledge expansion is not an attribute of an emergent phenomenon but indicates a situation comprising ‘differential elements’ (Deleuze, 1994, p.278) that are not easily integrated, such as the differences in method and content between engineering and art. Knowledge expansion is thus an indication of a fruitful collaboration and emergence.

6.2. Complementarity

Bringing different types of knowledge together in the workshop was expected to bring about complementarity – owing to different knowledge strands and different scientific methodologies. The data revealed strong evidence for complementarity characterised by different attributes and having different benefits. Among other things, it was found that the students bring complementary time horizons into play: ‘*EMSS thinks long-term and ArT thinks short-term*’ (unknown). Further, they reflected on the methodological differences as well as the embedded qualities and possibilities: ‘*I really liked working with new people from different background. It helped to open my mind towards art and helped me to understand concepts in a different way*’ (ArT student), ‘*Work with unknown people from different backgrounds’* (unknown), ‘*Another approach/method towards issues/their way of working and look at things*’ (unknown), and how this led to ‘*very different experiences because other methods were introduced*’ (ArT student). The acknowledgement and appreciation of complementarity is clear.

The responses also direct attention towards the experience of reaching outcomes that were more than the sum of each discipline and a direct consequence of non-linear interaction: ‘*Cross-disciplinary work leads you to places you would have never found by yourself*’ (EMSS student) and ‘*although working with such different students tends to feel like it is limiting your project, and you come up with very different solutions (from the ones you would come out alone), which is not necessarily bad*’ (ArT student). This element of complementarity refers to the experience of the two disciplines, both benefitting from the interaction. This finding strongly relates to the idea of synergism, which was presented to the students in the workshop introduction as one of the two dogmas.

That collaboration among students from different disciplines necessarily leads to mutualism with positive and reciprocal interaction is not a given. Inspired by biology, it is found that mutualistic interactions and benefits are most likely to develop between parts/organism with distinctive, different living requirements ‘between members of different kingdoms’ (Leigh, 2010, 2007). In our case, the authors have involved two quite distinct disciplines with very distinct research approaches, methods, and traditions. This might be one underlying reason for the experienced synergism, which is supported by a common approach through problem-based learning with a specified problem at hand relevant for both disciplines. However, a relevant reflection for future exploration is whether the students’ subject fields can be too different for positive synergism to take place.

6.3. Disciplinary self-reflection

The encounter and interaction with another discipline, representing different knowledge and different knowledge production processes, led to explicit attention being paid to the students’ own disciplines. For example, the awareness concerned the different foci: ‘*Today’s seminar made me aware of how much we EMSS students are often focused on technicalities and theoretical concepts* *rather than creative thinking and practical details*' (EMSS student). The data further indicate that the encounter with other methods and ways of thinking can inspire and possibly also raise the aspirations of the students. Some of the takeaways from their experience were as follows: '*My course is way more depressing than ArT*' (EMSS student) and that '*they [EMSS] had more realistic methods and mind-sets that I got inspired from*' (ArT student). One of the ArT students mentioned: '[I gained] *knowledge of how my competencies as an ArT student can be used outside of art*' (ArT student).

The enhanced awareness and thinking of their own disciplinary background and practice through the workshop participation is not full-fledged systematic reflective thinking, as described in the work of John Dewey, for example. Reflection defined as the 'active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and further conclusions to which it leads' (Dewey, 1933, p.118) cannot be detected in the case study. However, the cited experiences can create an impulse for the students to reflect more thoroughly on the inherent discourses and historically formed objectives and raison d'être of their own academic discipline. Important for our investigation is that disciplinary self-reflection creates an experienced difference, being a disturbance of learned disciplinary discourses. First, this is an increase in complexity because self-observation (reflection) becomes an intrinsic part of low-level systems that, second, could act as catalyst for transgressing discursive constraints of the students' respective academic discipline.

6.4. Change of practice

The overall response to the workshop was that these kinds of 'meetings' are examples of future inter-disciplinary work that is necessary to tackle environmental problems and the demand for sustainability. This is for example expressed as: '*Overall a good experience. It is interesting and practical to work with people that come from a complete different background, as it can work as an example of future projects*' (unknown).

Some of the respondents wrote that they would like to change their future project practice by adding some features from the 'other' discipline. Evidently, a change of practice is one result of a disciplinary self-reflection that most often is an eye-opener for missing or suppressed dimensions in one's own disciplinary discourse. For example, one EMSS student acknowledged the importance of emotions for a change of behaviour: '*I will try to remind myself of the focus on the emotional aspect of behavioural change in the future*' (EMSS student). Another EMSS student found another methodical opening for their discipline: '*Enjoyed seeing the ArT methodology; the idea of prototyping is something I will try to use in my own work from now on*' (EMSS student). Yet another concurred: '*Like the idea of prototyping, think I will keep it*' and '*in general, today's workshop was very inspiring and showed me how a bit of creativity could do our work very well*' (EMSS student). ArT students could see the value of quantitative methods and results to further artistic concepts and to '*look more at numerical and quantitative results to reason and explore concepts*' (ArT student). Suppressed dimensions in both disciplines were experienced and valued as being able to contribute to solution-finding regarding non-trivial societal problems.

For our purposes – the hoped-for emergence of non-anticipated concepts – the change of practice is an indicator of not only one additional learning outcome but also an opening or broadening of the students' individual practices to entail unfamiliar discursive aspects that potentially crack discipline-based and discipline-sustaining discourses. These cracks are the result of experienced differences and are a requisite for emergence. Cracks of this kind become part of the differential elements in a diachronic understanding of emergence (Protevi, 2006).

6.5. Play

Four students mentioned the importance of creativity, especially to be creative without the pressure of reaching a distinct solution. One student wrote: '*[…] and coming up with a concept, that we do not need to realise*' (ArT student). Another wrote: '*The day was very relaxed and pleasant, no pressure*' (EMSS student). And indeed, even though the workshop formed part of the students' curriculum, it was not in any way connected to an exam or a grade. The workshop established a particular space and time separated from the students' normal lectures and project work; a kind of play space and play time, a time for experimentation where there was no requirement for functional and realisable solutions whatsoever. This allowed the students (especially the EMSS students) to start off very differently. One engineering student took with him that '*being "crazier" and not to be afraid of the "unrealistic" ideas*' is a valuable thing; he continues: '*Use them as a starting point*' (EMSS student). Crazy and unrealistic ideas catapult the student far beyond the learned structures and paths of scientific methods and create a different starting point for solution-finding. However, all of us know that it is not that easy to leave our discursive and methodological boxes. To be able to do so, the workshop needs to establish a safe space – a 'playground' or 'magic circle' (Huizinga, 1949, p.77) – where a different set of rules is applied. Bateson asserts that a play space entails a meta-communicative layer: 'This is play' (Bateson, 1972, p.178) in contrast to everyday reality. The workshop intended to create a play-space that would support the creation of not-anticipatable solution concepts that, at this point, did not need to be put into practice. One element of play is that playing establishes an imaginary, quasi-fictitious level, which, however, is connected to the reality of the challenge of tons of PVC. Bateson uses the metaphor of territory and map, where reality is the territory and the map is the playful representation of reality that can be manipulated, changed, and rearranged. According to Gadamer (2004), '[p]lay fulfils its purpose only if the player loses himself in play' (p.102). This means that the workshop participants no longer need to commit themselves to the dialogical exchange of ideas and information concerning the problem (or riddle) given. This inter-disciplinary play works best when participants can accept this play-space where, at first glance, nonsensical or non-productive ideas and propositions can float. A potential creative and beneficial solution concept cannot be foreseen and is formed in the process of working with crazy and '*unrealistic ideas* (EMSS student)'. The workshop can be seen as framed playing (see the workshop requirements above) in that the students were asked to combine their different knowledge and methods in playful and non-goal-oriented ways.

7. Discussion: Learning for inter-disciplinary curriculum development for sustainability through art and engineering

The complexity of global challenges such as climate change, resource depletion, and biodiversity decrease demand new ways of thinking and require overcoming the 'traditional' disciplinary way of educating and problem-solving. This research aimed at exploring inter-disciplinary approaches in higher education for sustainability. This was done by bringing together students from art and sustainability science in a joint problem-solving workshop to address a concrete sustainability-related problem by departing from their unique knowledge, experience, and methodical perspectives.

To clarify, the purpose was neither to create works of art that deal with and communicate aspects of sustainability nor to design aesthetically pleasing disseminations of technical findings and solutions. The vision behind the intended interplay between art and science was the emergence of a third space of realisation and agency, where the historic/cultural distinction between the different epistemologies of art and science are revoked and where scientific discourses of factual mapping and generalisation interact with art's aesthetic and conceptual playfulness in a synergetic encounter that potentially leads to different kinds of solutions – solutions that are able to engage people on deeper affective and behavioural levels than the sheer implementation of technology can. The workshop concluded with the presentation of inter-disciplinary solution concepts that all were different than what the two authors otherwise empirically see of mono-disciplinary concepts. In this respect, the presented solution concepts showed indications of emergence.[2]

Our specific research focus was on mapping the experiential conditions for (1) synergy between disparate approaches and their intrinsic discourses that (2) potentially could lead to the emergence of concrete solution concepts for sustainability. Our research indicates that the existence and mutual recognition of differences support emergence. As Deleuze claims, difference is the basic ontological condition where instability yields emergence in the form of continuous instantiations. Instantiations entail changes and modifications. Thus, the emergence of novel solution concepts evidently is based on intentionally staged differences that produce situations of instability. For example, none of the workshop participants could rely on known and rehearsed methods but together they had to create mutual ways of tackling the challenge of 30 tons of PVC. In our case, recognised differences must be understood as collisions between different conceptual matrices (Koestler, 1977; Heinrich, 2018). Our workshop deliberately put on stage, first, scientific causal logic where the solution concept is found by means of reasoning based on recognised facts and, second, associative correlations based on aesthetic perception and affection. The tension between these conceptual matrices entails many small differences, such as the abstract weight of 30 tons and the affective imagination of being buried under a huge pile of PVC or the categorised characteristics of PCV and the tactile feeling on your skin when wearing clothes made of PVC. Note that this is not a tension between people but rather between different approaches to problem-solving.

Our research shows that the workshop participants experienced these differences as 'knowledge expansion', 'complementarity', 'disciplinary self-reflection', and 'change of practice' within a 'play'-ful setting and mindset. 'Knowledge expansion' expresses the experience that a chosen approach is a kind of observational grid that always shuts something out that cannot be recognised. Scientific methods shut out aesthetic affective dimensions as irrational, and artistic-aesthetic methods render invisible causal argumentation and concrete problem-solving.

The benefit for EMSS students and their programme was the broadening of their approach to also include emotional and experiential aspects that could uncover aspects not accounted for by this academic field and to open up completely different types of participation and inclusion of individuals. Conversely, ArT students became aware of the meeting of associative and aesthetic discourses with fact and causal, logic-driven approaches to solution-finding.

When the tension between these discourses is experienced as potentiality, it is complementary in that the tension sheds light on what the respective mono-disciplinary approaches exclude and make indiscernible. Complementarity is still a state of tension, albeit a tension that already contains the seeds of emergence of solution concepts. An effect of complementarity as productive tension is 'disciplinary self-reflection', which is an incipient second-order observation on the possibilities and impossibilities of one's own study and, important for emergence, the prospects of other approaches. 'Disciplinary self-reflection' and the consequent possible 'change of practice' express the participants' mental and psychological openness to bring differences into interplay.

The inspiring and productive play of differences needs a proper framing that allows and secures playing as an activity that defines its own internal and recursive purposes. In our case, the purposes are to experience the combinatory and potentially emergent properties of inter-disciplinary creation in light of a defined problem.

Inter-disciplinary higher education for sustainability varies in mission, context, and composition. As the results of this exploratory research indicate, realised and workable differences between participating disciplines are of great importance when the goal is to support emergence for the development of concepts for solving sustainability challenges. Complementarity, mutuality, and disciplinary self-reflection are based on difference. To make this difference operational and beneficial, a designed setting is necessary. The educational setting of problem-based learning specified that all participating students must work towards a mutual goal that is envisioned on an emergent level. This common goal of an unknown solution can already be understood as an incipient 'downwards causation' (Campell, 1974) in that it forms the ongoing evaluation of the process and the emergent conceptual ideas. Through the encounter with 'the differential', students are given an invitation to take a position through which they can see and reflect on their own practice, ontology, and epistemology and be inspired and challenged to a degree that potentially produces emergent elements in their problem-solving. This bring up implications for the planning and undertaking of inter-disciplinary workshops, and the results suggest that in an inter-disciplinary learning environment, the degree and modality of difference is central.

8. Conclusion

As a slightly unconventional concluding section, the authors want to briefly analyse the above-described solution concept, the PVC graveyard, because this solution concept entails many of the points elaborated above in a metaphorical form. Seen from an artistic perspective, the idea of PVC graveyard alludes to works of art that present processes of decay (for example, Lemmerz' work *Scene* (1994) showing decaying pigs in exhibition cases) or, on the contrary, processes of preservation (for example, Hirst's *The Physical Impossibility of Death in the Mind of Someone Living* (1991) showing a tiger shark in formaldehyde). The concept theatrically and anthropomorphically stages the fate of this material, which is to be dumped in a landfill. The idea simultaneously works on an emotional, associative level and on a factual, documentary level. Graveyards and mausoleums are associated with funerals and grief. The airbeds are re-contextualised, estranging both airbeds – generally useful everyday objects – and human graveyards as sacred places of transcendence. Everyday merchandise and scientific facts are shrouded with an atmosphere of human loss and holy transcendence. The staged situation is at the same time ridiculous, sad, and severe. Seen from a purely engineering perspective, the concept of the graveyard does not contribute much to the technical solution of this problem if we were to understand this as the development of new materials that could replace PCV or the formulation of laws and rules that prohibit the use of PCV in the fabrication of goods. The concept only states that at this moment in time, PVC products cannot decompose but can only be buried. However, the festival participants' potential realisation of the severe ecological consequences of the thoughtless dumping of hardly used PVC airbeds by means of artistically staged scientific facts and the envisioned change of consumer behaviour must also be seen as a responsibility with which engineering and the arts must deal.

The main lesson learned is that even a short workshop with university students from different programmes working on a predefined problem already entails all the ingredients and potential for emergent ideas. Our findings point towards a necessary awareness of differences rather than similarities and harmonies. Therefore, future work should carefully stage and highlight differences as catalysts of, first, the generation of solutions that are able integrate technological, affective and behavioural dimensions and, second, student learning. Student learning (disciplinary self-reflection, knowledge expansion, change of practice) goes hand in hand with solution generation (mutuality, complementarity, play). Staging differences means, for example, to give words to and discuss differences in subject areas, methodologies and discourses, to form working groups based on selected parameters of differences, and to formulate a research problem that can be approached from various angles. But it also means to allow for uncontrolled and, on the face of it, idle time and space, where differences can be played out in the light of the problem at hand. Future work within this pedagogical field should more thoroughly orchestrate, map and analyse differences and their combined effects for both learning and solution finding.

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[1] Defined as 'the interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects' (Oxford Dictionary).

[2] We are aware that the envisioned aim is not novel at all. The entire art and science movement, which has existed for several some decades, is driven by this objective. Furthermore, there are several pedagogical projects that intend to introduce aesthetic and creative approaches to teaching and learning at various levels. Therefore, our workshop must be seen as part of a broader aspiration to bring about an extended notion of and framework for knowledge production that actively integrates analogical and aesthetic dimensions in learning and solution-finding projects regarding sustainability.