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Relate Systems Archetypes and Collaboration: A case study in the context of DIY bio-based materials in design education

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Introducing sustainability and circular economy (CE) in higher education is becoming a key instrument for tackling climate change. When we look at design curricula, several skills are required for designing for circularity among which the systems-oriented focus and the intrapersonal skill of collaboration. In this paper, we report on a case study where 15 teams of design students re-designed a university system to enable the use and development of DIY bio-based circular materials. Specifically, what we observed is the correlation between the systems archetypes used by the students both diagnostically and prognostically (Braun, 2002) and the number of collaborations the students created with other teams and external stakeholders. Results show that by adopting a systemic view, students could take in consideration possible positive and negative effects of (not) collaboration with other actors in their system. It is not yet explored the depth of this correlation, which could become a focus of future studies.

Keywords: Systems Archetypes; Systems Loops; Design Education; Collaboration; DIY bio-based materials.

Introduction

Introducing sustainability and circular economy (CE) in higher education is becoming a key instrument for tackling climate change (Bocken et al. 2016; de los Rios and Charnley 2017; Wiek, Withycombe, and Redman 2011). In the field of industrial design engineering several approaches to *design for circularity* have been proposed, one of which is the focus on valorising biological streams. In this broad context, the development of new materials, often DIY, circular and bio-based constitutes an interesting focus to be explored further. So far, there has been little discussion about how to replace traditional materials with these more sustainable alternatives. Few studies are emerging to find solutions to turn waste into new products (Camere and Karana 2018; Rognoli et al. 2015; M. Sauerwein and Doubrovski 2018; Marita Sauerwein, Karana, and Rognoli 2017). To help speed up this process design students should gain the right knowledge and skills (de los Rios and Charnley 2017; Sumter et al. 2020). If we look at the design stage, we discover that to be able to design for sustainable innovations, the outcome should be systems-based rather than solution-based (Charnley, Lemon, and Evans 2011; de los Rios and Charnley 2017; McMahon and Hadfield 2007; Wiek, Withycombe, and Redman 2011). Finally, to implement this whole system design, designers should collaborate to optimize the system rather than optimizing one implementation of a material (Blizzard and Klotz 2012).

State of the art

Currently, one of the most widespread models to represent the circular economy is the so-called “butterfly diagram” proposed by the Ellen MacArthur Foundation (Ellen MacArthur Foundation 2019). This model reports on two main streams: a technical and a biological one. In the industrial design engineering field strategies to “close loops” on the technical cycles are becoming more and more common (Despeisse et al. 2017; Nascimento et al. 2019). A lot of examples to design services systems for reparation, reuse, maintenance, etc. can be found (Bocken et al. 2016; Hopkinson, de Angelis, and Zils 2020). Vice versa, the biological cycles are yet hard to address. There are multiple ways to address the implementation by design of the biological cycle. In this paper we focus on one possibility; the development and implementation of so-called bio-based circular materials, as for example: mycelium-based materials, bio-based leathers, etc. Although these materials are gaining interest from many actors of the value chain, only few industrial examples exist. As prove of this gained interest, many DIY and open-source versions of these materials have been developed and can be found in online database such as Materiom and BioFabForum.

System approach to design and the value of collaboration

McMahon and Hadfield note in 'The butterfly effect" that a holistic approach is needed to create sustainable design solutions and that designers should take the lead in restructuring these systems (McMahon and Hadfield 2007). Wiek's definition of the systems-thinking competence is "System-thinking competence is the ability to collectively analyse complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks" (Wiek, Withycombe, and Redman 2011). To gain insight in the patterns and behaviours happening in a system Braun (2002) suggests using archetypes as a diagnostic tool. These archetypes might be used to gain insights in the system integrating and using bio-based circular materials by the user.

In her analysis of circular economy competences for design, Sumter (2020) identifies seven core competencies. Among these seven competences there are three of them that refer to collaboration with stakeholders; circular user engagement, circular economy collaboration and circular economy communication. This view is supported by McMahon and Handfield who listed communication and co-operation as pathways to systems thinking for sustainable design solutions (McMahon and Hadfield 2007). Wiek even goes further and argues that the interpersonal skills are the crosscutting key competence in enabling sustainability (Wiek, Withycombe, and Redman 2011). The research to date has tended to focus on stating the importance of the competency of collaboration rather than on techniques and suggestions how to implement collaboration for sustainability in design education. Furthermore, industries interest in collaborating to reach sustainability is growing too (Fadeeva 2005; Kiron David et al. 2015; Lozano 2007) it might be worth to prepare students for these collaboration skills. (Cairns, Hielscher, and Light 2020; Wiek, Withycombe, and Redman 2011)

This paper explores how system thinking relates to the student's attitude towards collaborations (seen as interpersonal competence) and how it can be implemented in the design curriculum of industrial design students.

Methodology

This study is based on the case of design students working on DIY bio-based circular materials. For 12 weeks, 45 bachelor industrial design students, divided in 15 teams, have been trained in systems design, including the use of systems archetypes and feedback loops. Students got assigned different yet related design challenges of which some were more material based, starting from an existing recipe of a DIY bio-based material while other challenges where more overarching the other teams. For example, focusing on the end-of-life strategies. The course was a mix of practice and theory, where students got information about the systems-thinking; systems archetypes; and feedback loops reading and writing (Braun 2002). The students were challenged to bridge the practice of working with DIY bio-based materials and the given theory. Furthermore, they were asked to upload two types of deliverables:

1. Weekly highlights including the key findings and/or experiences that took place in that specific week (33 per team in total).

2. Starting from the one proposed by (Braun 2002) students were invited to share the "applied" systems archetypes relevant to their system.

In this study the relation between using systems archetypes and the level of *collaboration* is studied with more detailed research questions.

1. What is the number of within-class collaborations (with other teams)?

2. What is the number of outside-class collaborations (with different actors)?

3. Is there a link between the amount of within-class and outside-class collaborations and the archetypes analysed by the students throughout the course?

In this study, collaborating means working together with other teams inside the class (within-class collaboration) or stakeholders outside the class (outside-class collaboration) to achieve the goal of their design challenge.

Data analysis

To verify the extend of collaborations we counted the times each team mentioned in the "weekly highlights" one of the other teams. With Graph Commons we visualised a more detailed information on the amount and nature (one- or two-way) of the occurring collaboration. To analyse the relation between the used archetypes (Braun 2002) and the number of collaborations, we analysed in depth the way students used and appropriated archetypes to their design context. In this paper only two teams have been here reported.

Results

Within-class collaboration

The table below shows the number of times a team mentions another team in the weekly highlights.

Table 1. Team, category and number of mentioning or being mentioned in daily highlights.

Team Num.	Subject of the team	Category challenge	Num. highlights mentioning teams (of 33)	Num. teams being mentioned (of 14)	Num. teams that mention this team (of 14)	Num.two-sided connections
1	Mycelium based materials	Material-driven	10	10	6	5
2	Kombucha leather	Material-driven	0	0	3	0
3	Natural fibres with releaf	Material-driven	3	2	3	1
4	Bio colors in prototypes	Material-driven	3	3	3	1
5	Devel'up 2.0	Material-driven	0	0	2	0
6	3D printing eggshell	Material-driven	1	1	3	0
7	3D print coffee	Material-driven	/	/	/	/
8	Wilderness in design	Overarching	5	4	3	2
9	Silicon mold substitution	Material-driven	3	2	2	1
10	Knotplex application	Material-driven	5	4	3	1
11	Press for biomaterials	Overarching	0	0	5	0
12	Wooden chips	Material-driven	4	3	2	1
13	Bridging academia and industry	Overarching	8	6	4	4
14	End-of-life	Overarching	2	2	4	2
15	Connections in prototypes	Overarching	16	14	4	4

To visualise the connections in the list above, the data is imported and visualized using Kumu to show the interrelation between these teams.

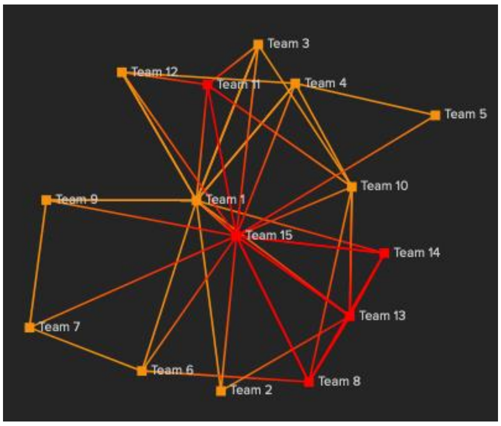

Figure 1. Visualization of the interclass collaborations. Each link represents if a team has mentioned another team or has being mentioned in the "weekly highlights". The red dots represent teams with an over-arching design challenge, the orange lines represent teams with a material-based design challenge.

Interestingly, we can observe connections between all 15 teams. In table 1, we can see that not all the teams mention other teams in their daily highlights. These teams are nevertheless get mentioned by other teams (generating a one-sided connection).

One-sided or two-sided collaborations

To see more in detail how these teams are connected we used the weighted data (number of times a daily highlight mentions a team) and the information about who mentioned who. This way the one-way and two-way connections could be analysed. To visualize the one- or two-sided connections and the more detailed information, the data is imported in Graph Commons. The number of two-sided connections in table 1 is a result of counting the two-sided connections generated by Graph Commons.

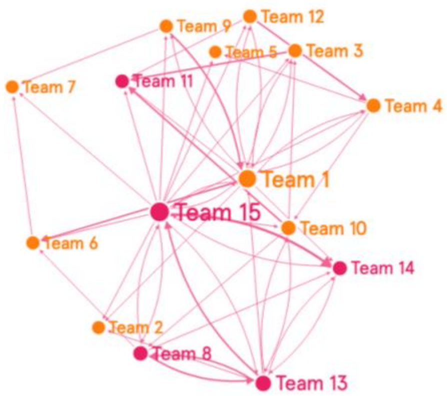

Figure 2. Visualization (Graph commons) of the interclass collaboration of all the teams. The thickness of the arrow represents the number of times the team mentions the other team (in this study this number lays between 1 and 3 times). The arrow represents who mentions who.

The following paragraph shows a close-up of one team with a material-driven design challenge (Team 1) and of one team with an over-arching design challenge (Team 13).

Examples Teams 1 and 13

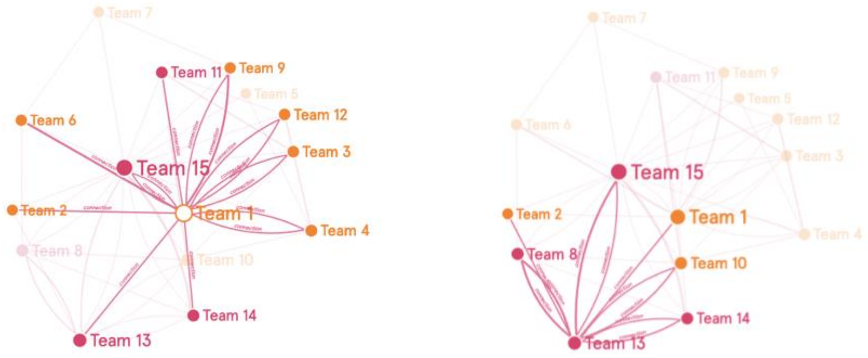

Figure 3. Visualization (made with Graph Commons) of the interclass collaboration of (from left to right) Team 1 and 13. The arrow displays who mentions who. The thickness of the arrow represents the number of times the team mentions the other team. Both one-sided and two-sided connections are visible.

Team 1 managed to connect with 10 other teams from which 5 out of 10 mentioned Team 1 in return in their weekly highlights (two-sided collaboration). Striking to see is that from the five two-sided connections of Team 15, a team working on a material-driven design challenge, 4 teams had a material-driven design challenge too.

Although Team 13 has an overarching design challenge they do not reach the highest number of interconnections. But if looking in detail they mention the same teams several times and these teams they mention, mostly mention them back (two-sided collaboration and prolonged in time). From the four two-sided collaborations, three of them have just like team 13 an overarching design challenge.

Outside-class collaboration

The outside-class collaborations were analysed in an analogous way as analysing the inter-class collaboration by counting the weekly highlights, now counting the number of weekly highlights mentioning a stakeholder and how many categories of stakeholders were touched upon in these weekly highlights (table 2). These stakeholders were categorized in six Stakeholder groups listed in Table 2.

Table 2. Categories of stakeholders

Number	Category name	Description of the stakeholders
1	Atelier	The atelier is the name of the workshop at Ghent University Kortrijk it involves the staff using, maintaining and managing the workshop.
2	Students inside the course	Students subscribed to the course
3	Students outside the course	Students outside the course (other years, or other curricula – since the atelier where many experiments tool place is shared)
4	Lecturer outside the course	Lecturers using the workshop for classes
5	Material sourcing company/organisation	Companies or organisations with bio-waste streams that could be collected and used by the students
6	Others, outside university	Everyone not fitting inside the other categories listed above

Table 3. Team, category and number of mentioning or being mentioned in daily highlights.

Team Number	Subject of the team	Category challenge	Number of stakeholder categories mentioned (out of 6)	Total weekly highlights mentioning a stakeholder (out of 33)
1	Mycelium based materials	Material-driven	3	4
2	Kombucha leather	Material-driven	2	10
3	Natural fibres with releaf	Material-driven	2	3
4	Bio colors in prototypes	Material-driven	2	6
5	Devel'up 2.0	Material-driven	1	5
6	3D printing eggshell	Material-driven	3	7
8	Wilderness in design	Overarching	1	2
9	Silicon mold substitution	Material-driven	1	4
10	Knotplex application	Material-driven	1	2
11	Press for biomaterials	Overarching	0	0
12	Wooden chips	Material-driven	2	3
13	Bridging academia and industry	Overarching	4	9
14	End-of-life	Overarching	3	6
15	Connections in prototypes	Overarching	5	12

Two teams (Team 7 and 11) did not mention any stakeholders at all in their weekly highlights. Nine out of fifteen teams mentioned students outside the team in their weekly highlights. The atelier is only mentioned by two teams as a stakeholder (Team 14 and team 13). Material sourcing is only mentioned by three teams (Team 3, 6 and 15). Other stakeholders outside the university are mentioned by 4 teams. (6,13, 14 and 12). Three teams (team 1,2 and 15) approached other lecturers to implement bio-based circular materials in their course.

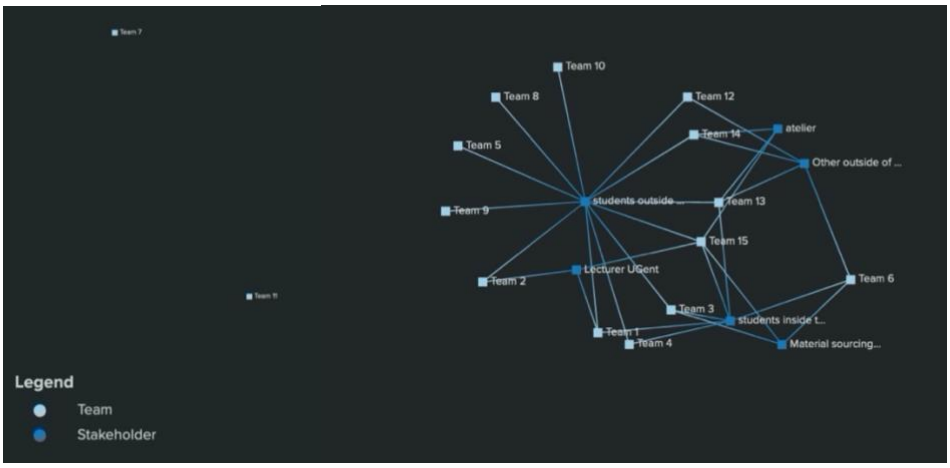

Figure 4. Visualization of teams and categories of stakeholders (made with kumu) mentioned in the weekly highlights.

Analysis of the relation between the inter-class and outer-class collaboration and the archetypes

Team 1

Team 1 scored high on the inter-class collaborations, they managed to create 5 two-sided inter-class collaborations, which is the highest reached in this study. Team 1 only mentioned stakeholders in 4 of the weekly highlights. Compared to Team 15, who mentioned 12 times a stakeholder, Team 1 scores rather low on the outside-class collaboration. When looking at the archetypes of Team 1, they modelled 6 archetypes, Using the limits to growth, success to the successful and 3 balancing feedback loops. Team 1 filled in all the archetypes implementing no stakeholders and no other teams, they used the feedback loops only to describe the technical parameters (growth, process, available space) of the mycelium.

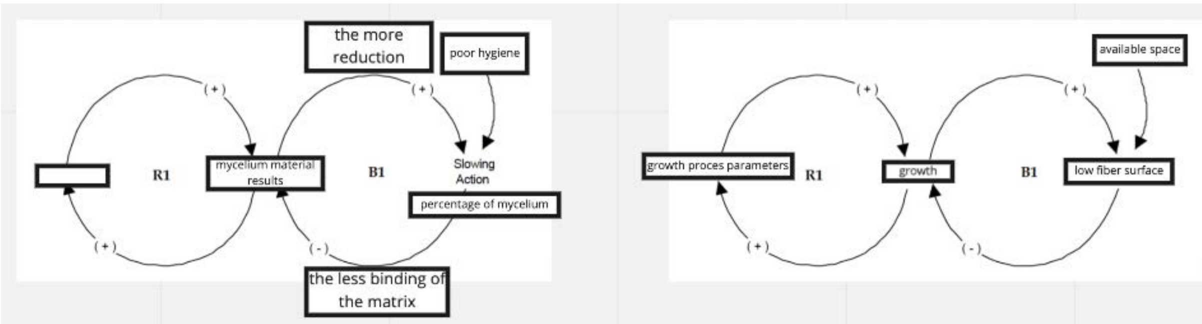

Figure 5. Team 1: Basil Bataille, Maité Priëels and Casper Van Herzele; two descriptions of an archetype 'Limits of growth'.

Team 13

Team 13 mentioned or got mentioned by 6 teams in the weekly highlights, 4 of these connections with these teams were two-sided collaborations. They had less but stronger connections compared to team 15. Team 13 made 8 archetypes, three of them contained stakeholders, the other five mentioned the other teams. In figure 7 the students describe how the interaction between the teams can be higher by using the Instagram page. During the feedback session the students mentioned that it was hard to reach some teams. The teams did not see the value yet of the collaboration proposed by Team 13. The strategy of Team 13 was work together with the teams they were able to reach, hoping that once there where results to be shown, the other teams would follow. This might be linked to the fact that in the weekly highlights they mentioned less teams but the amount of mentioning them was high.

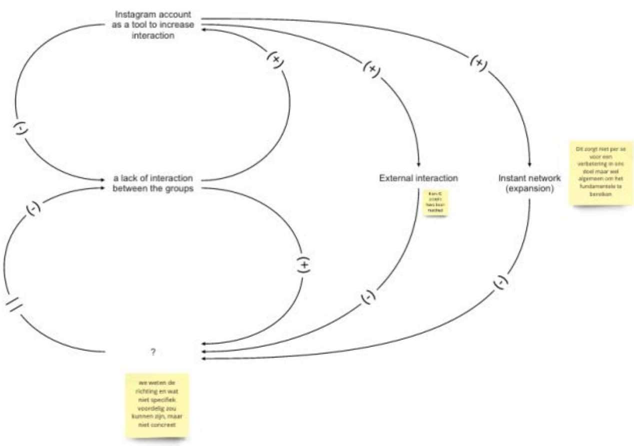

Figure 7. Team 13; Lotte Beernaert, Alesio Descamps, Interpretation of the archetype 'shifting the burden'.

Discussion

In this paper we explore the value of teaching systems to trigger the interpersonal skill of collaboration. Yet, this might not be enough to enable corporative collaboration – since the barriers highlighted today for such collaboration is clearly also institutional. This paper focuses on design education, although there are insights that could be talking to industry, it is important to note that in the design challenge the students needed to design a system that would be self-sustaining but not necessarily create monetary value. The 2 analysed cases show a link between using a certain archetype and collaboration with other teams and stakeholders. Further research should be conducted to see if the archetypes trigger the collaboration, or the collaboration trigger the archetypes.

Looking at the results, the students are collaborating with other stakeholders within-class and outside-class, yet the amount is not at its highest. Teams with a material-based design challenge tend to focus on technical aspects, they struggle understanding the importance of engage others, when engaging with other teams it seems that they more often collaborate with other teams working on a material-based design challenge. On the other hand, teams with an over-arching design challenge have more often a collaboration with other teams with an over-arching design challenge, for these teams it is harder to reach out to teams with a material-based design challenge. Finally, this study does not look at the quality of the collaboration, although the quality could be of high importance.

Further research should be conducted to see what influences the view on the archetypes and if it is possible to give students the tools to change their view from seeing their peers as competitors to collaborators or as we like to call it; strive for co-opetition.

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