

Cultivating students' sustainability-oriented learning at the interface of science and society: a configuration of interrelated enablers

Interface of
science and
society

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Valentina C. Tassone, Perry den Brok, Cassandra W.S. Tho and
Arjen E.J. Wals
*Education and Learning Sciences Group,
Wageningen University and Research, Wageningen, The Netherlands*

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Abstract

Purpose – By envisioning the learning environment as an eco-social system, this study aims to map interrelated enablers of students' sustainability-oriented learning (SoL) in the context of a university course at the interface of science and society.

Design/methodology/approach – A case-study approach was used to delineate what enables student learning in a university-wide transdisciplinary Master of Science course. A sample of 102 students, university and societal stakeholders participated to this study, by sharing their experiences and views through focus groups and questionnaires.

Findings – A main finding is the development of a configuration of six intertwined enablers that through their interplay help to cultivate students' SoL, in the course under exploration.

Originality/value – This study paves the way for a re-orientation of how to explore learning in complex environments. It shows that adopting a relational, situated and systems approach is not only feasible but is also desirable to understand and guide learning practices in complex environments.

Keywords Sustainability, Higher education, Eco-social system, Enablers of learning, Science-society, Transdisciplinary learning environments

Paper type Research paper

1. Introduction

Higher education institutions all over the world are looking for ways, within courses and curricula, to engage students responsibly in sustainability challenges affecting both humanity

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and the planet (UNESCO, 2015). Sustainability challenges – from curbing runaway climate change, to maintaining biodiversity, to ensuring human health and well-being for all – are complex, involve multiple perspectives and affect both natural and human systems (Liu *et al.*, 2015). To respond to these challenges, it is considered crucial to move beyond disciplinary and sectoral silos (Norström *et al.*, 2020) and to engage with deep forms of learning (McCrorry *et al.*, 2021). In response to the call for more integrative approaches, a shift within higher education courses and curricula can be observed towards the creation of complex and transdisciplinary learning environments or spaces (Vilsmaier and Lang, 2015). These types of learning environments attempt to connect science and society: they bring together students, scientists and members of society with different backgrounds, vantage points and personal qualities to address real-life sustainability challenges.

In such complex environments as those described above, cultivating students' sustainability-oriented learning (SoL) requires careful consideration. To organise educational, teaching and learning practices within those complex environments, a number of studies have explored in-depth single specific features or enablers of learning. For example, some authors highlighted the crucial role of educators, their ways of thinking (McCune *et al.*, 2021) and their capacities to enable student learning by navigating complex collaborative environments (Di Giulio and Defila, 2017). Others emphasised the usefulness of pedagogical frameworks fostering transdisciplinary reflexivity (Fortuin and Van Koppen, 2016) and engaging students in processes of learning across multiple domains of being, knowing and doing (Sipos *et al.*, 2008). Still others identified activities for nurturing students' complex sustainability competencies (Caniglia *et al.*, 2016) and developed boundary-crossing evaluation tools (Gulikers and Oonk, 2019) to foster student learning.

The relevant in-depth exploration of those specific enablers, however, also goes hand in hand with an emerging recognition in literature that learning spaces need to be explored not only in terms of individual features enabling learning, but more relationally and as a system. In fact, some scholars (Barnett and Jackson, 2019; Wals, 2019) call for a re-orientation of how learning is investigated in increasingly complex environments. To explore how learning is enabled, they advocate embracing a more relational and ecological view and call for the adoption of a systems perspective. While this approach provides theoretical and conceptual support for such a re-orientation, hardly any empirical research has been done on its enactment within higher education courses that address sustainability challenges.

By taking a systems perspective towards a learning environment, this study aims to map a configuration of interrelated enablers that can help to cultivate SoL of students in a university course focused on bridging science and society. This aim is pursued by investigating the experiences and views of students, university staff and societal stakeholders in a sustainability-oriented transdisciplinary Master of Science course offered at Wageningen University and Research (WUR), a life sciences university in the Netherlands.

The next Section 2 elaborates on the study context and delineates the conceptual lenses that guided the study. This is followed, in Section 3, by a description of the research design, instruments and analysis. Then, Section 4 presents a configuration of six interrelated enablers that help to cultivate students' SoL. Discussion and conclusions in Section 5 and 6 end the paper.

2. Contextual and conceptual background

2.1 Study context

The study context is a sustainability-oriented transdisciplinary and international Master of Science course at WUR. WUR is an international, medium-size university, focussing on the domain of "food and living environment". The course under exploration, called "Academic Consultancy Training" (ACT), runs every eight weeks (for a total of 252 study hours) throughout the school year. It is a university-wide course involving over 1,200 WUR students annually, who

are enrolled in 20 diverse social and technical sciences study programmes and typically represent more than 100 nationalities. The course also involves representatives from about 170 societal organisations as stakeholders and about 200 WUR staff members (academic advisors, coaches, teachers and intermediaries between the university and society who are called brokers).

The aim of the course is to engage students in a process of transdisciplinary research endeavour and capacity building. In this process, societal stakeholders present sustainability challenges and students are called to respond to them in a responsible manner. Students form an academic consultancy team typically consisting of six members from diverse disciplines and often from different cultural backgrounds. The members of organisations in society (e.g. governments, businesses, non-governmental organizations and civil society) issuing the challenge they encounter in their work are called “commissioners”. An important role of WUR staff is that of “broker”: someone who brokers a relationship between the commissioners and the ACT student teams and, in a sense, creates a bridge between science and society by selecting and negotiating topics suitable for the course.

Each ACT student team works on a specific sustainability real-life challenge for a total of eight weeks. In the first four weeks, each team collaboratively develops an academic consultancy project proposal by assembling academic and practical knowledge. In this project proposal, the student team defines the underlying transdisciplinary challenge, study goals, research questions, methods of research and analysis and activities and outputs in collaboration with the commissioner and a WUR staff consisting of academic advisors, coaches and teachers. In the following four weeks, each student team collaboratively executes the proposed research, integrates the academic and practical inputs received from relevant parties and provides scientifically sound and practically relevant advice on how to possibly respond to the sustainability challenge at hand. The ACT commissioners and the WUR staff contribute to the students’ research in several ways. The commissioners provide contextual knowledge and reflections. The academic advisors share scientific knowledge and support the academic development of the project. The coaches support student team building, transdisciplinary collaboration and personal development. The course teachers provide students with concepts and tools concerning transdisciplinary collaboration, communication and personal development. The ACT course design and the different roles of the people involved in it are depicted in [Figure 1](#).

When taking the course, the students are expected to achieve a number of SoL goals including:

- being able to collaboratively design and execute an academic consultancy project, bridging science and society, to respond to real-life sustainability challenges;
- engaging in multi-perspective reflection and communication;
- demonstrating creative, critical, ethical and transdisciplinary capacities for working within complex real-life contexts; and
- achieving a synthesis of the multiple insights generated and delivering integrative, responsible academic consultancy advice and related outputs.

In short, the transdisciplinary context, aim and learning goals of the ACT course are intended to foster a SoL that is relational, responsible and responsive. It is relational because of the underlying interpersonal, intersectoral and overall transdisciplinary character of the learning taking place at the interface of science and society; it is responsible because it generates critical and ethical reflections with respect to the sustainability challenge at hand and to the vantage points of those involved in the challenge or affected by it; it is responsive

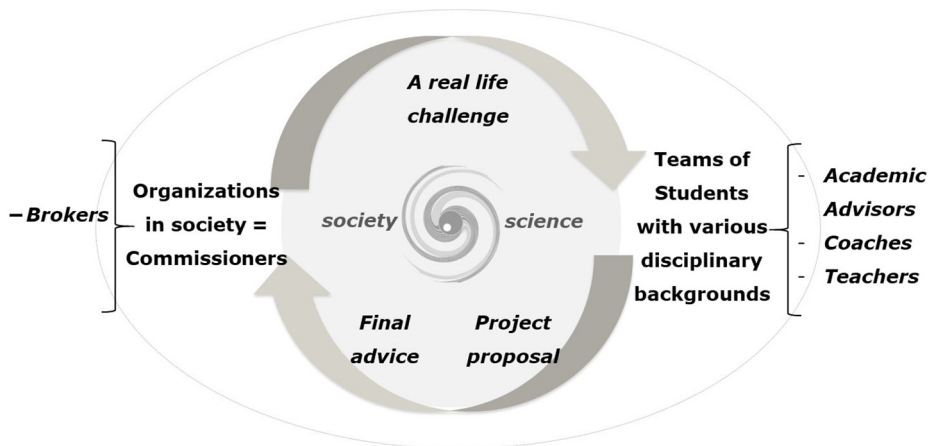


Figure 1.
ACT course design

because it entails the creation of integrative consultancy advice for responding to a given sustainability challenge in society.

2.2 Conceptual background

This study draws on the concept of transdisciplinarity to define the learning environment in which the study takes place and adopts an eco-social system perspective to investigate what enables students' SoL in such an environment.

Transdisciplinary learning environments attempt to bridge science and society and encourage forms of cross-boundary research, collaboration and deep learning (Budwig and Alexander, 2020). Those environments include a variety of academic and societal stakeholders and support endeavours of integrative knowledge creation and capacity building, with the purpose of addressing challenges in society (Polk, 2015). The characteristics of such complex learning environments also depend on the type of engagement of the stakeholders involved (Schauppenlehner-Kloyber and Penker, 2015). For example, all involved stakeholders can function in the same way throughout the transdisciplinary endeavour, or they can perform different roles, with some of them in charge of this endeavour while others mainly provide feedback (Mobjork, 2010). The context of this study reflects a differentiated form of stakeholders' engagement, focussed on academic consultancy. This entails that the students, in their role of academic consultants, are in charge of the transdisciplinary research endeavour and address a sustainability challenge by applying, extending and integrating their knowledge and capabilities with those provided by the other stakeholders. In turn, the academic and societal stakeholders engage by sharing their feedback, knowledge and capabilities with the university students conducting the research.

Within this transdisciplinary environment, this study draws on the concept of eco-social systems to investigate what enables students' SoL. Since its introduction in the early 1930s (Pickett and Cadenasso, 2002), the concept "ecosystem" has been extensively elaborated and has also come to denote an ecological system constituted

by interdependent biotic and abiotic components, namely species and their surroundings which are in complex relationships with each other. The concept of ecosystem can also be used as a metaphor to describe complex environments, for example educational and learning environments. Educational ecosystems can be constituted by interrelated components such as the *people* engaged (e.g. students, teachers and stakeholders), things or means characterising the surroundings like the educational *structures* (e.g. curricular activities, materials and resources,) and the *pedagogies* (approaches in teaching and facilitation), as well as their overall dynamic relationships supporting learning (den Brok, 2018; Jackson, 2020). By further transferring the concept of ecosystem into a human and social learning context, and by drawing on classical systems theory, Lemke (1997, 2000) pointed out that what is so generative about an eco-social system is that it combines interrelated *people*, *structures* and *pedagogies* with *processes*. The processes or pathways of learning, dialogue and other forms of interaction are thus also an integral part of an eco-social system.

In line with this thinking on eco-social systems, the current study also considered that the overall dynamics of such a system depend not only on the relationships among its interrelated components, but also on what those components mean to those engaged in the system. It is through participation in what Lemke (1997) called “micro-ecologies” of situated practices with other people, things and processes that meanings are created. Within such situated practices, the persons involved can use their experiences, perceptions and positionality to define what they value, what they consider supportive for learning and so forth. In sum, acknowledging the relationships among *people*, *structures*, *pedagogies* and *processes* and the *meaning-making* of the people involved, constituted the starting point for mapping enablers in this study. These enablers, once they are in place in the course system, make up a configuration that helps cultivate students’ SoL in this transdisciplinary study context. The conceptual background guiding this study is depicted in Figure 2.

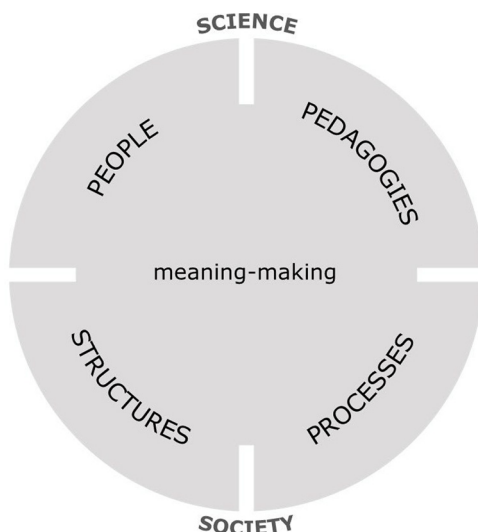


Figure 2.
Guiding conceptual
background

3. Research design, instruments and analysis

3.1 Research design, sample and data-capturing instruments

To explore what enables students' SoL in the context of the ACT learning environment, this study used a qualitative case study approach (Merriam, 1998). This exploration engaged a total of 102 people who were involved with the ACT course over a specific eight-week period. Those 102 people comprised the following categories. Firstly, there were 33 students, each of whom had functioned as the "manager" and representative of one of the 33 student teams enrolled in the course during the eight-week period of investigation. The second category comprised all 27 coaches that coached student teams involved during that same period (some coaches were coaching two student teams). Next, there were 5 teachers and 5 brokers involved, as well as 15 academic advisors and 17 commissioners. While an additional 18 academic advisors and 16 commissioners had taken part in the course, they did not respond to the invitation to take part in the current study. The views of the students, coaches, teachers and brokers were explored by means of focus group conversations. The views of the academic advisors and commissioners were explored by means of open-response online questionnaires. The focus groups, as well as the distribution of the questionnaires, took place in the last few weeks of the eight-week period under investigation.

The focus group method (Krueger and Casey, 2015) invited participants to share experiences and views on what enable students' SoL within the ACT sustainability-oriented course. In the focus groups, open guiding questions were used to allow a dialogue to emerge. A total of ten focus groups were conducted: four focus groups with students, three with coaches, one with teachers and one with brokers. Each focus group lasted about 1 h and included only one category of respondents, with a minimum of five and a maximum of nine participants per focus group. The focus group conversations were implemented through a loosely structured protocol and were facilitated by the first author and a facilitator from outside the team of co-authors. At the start, the ACT SoL course design, aim and learning goals were mentioned to bring focus to the study context. Then, the following guiding question was introduced and was reiterated throughout each conversation: "What helps cultivate students' learning within the ACT context?" The participants reflected on this question, while considering features that were already in place or that could be better positioned in the course to enable student learning. The participants shared their experiences and views, based on their roles and engagement as students, coaches, teachers or brokers. The focus groups were videotaped (with permission of all participants).

Furthermore, an open-response questionnaire was used to explore the views of academic advisors and commissioners. The use of a questionnaire was necessary for these respondents, given the impossibility of organising focus groups at fixed dates with commissioners located in different countries, and with academic advisors often abroad for work. The questionnaire was conducted online by means of Qualtrics (www.qualtrics.com). A link to the online questionnaire was sent to the academic advisors and commissioners involved. The same guiding question used for the focus groups was asked when introducing the questionnaire. The respondents were then requested to report on their experiences and views in the questionnaire, taking into consideration the same discussion topics introduced for the focus group and keeping in mind their role in their course.

Given that the first author performs coordination tasks in the ACT course, additional perspective was supplied by inviting three co-authors not involved in the course to take part in the study, the scrutiny of the data and the elaboration of the findings. The role of those co-authors is explained in the next section.

3.2 Analysis

The data was subjected to thematic analysis, using an iterative process (Boyatzis, 1998). The focus group conversations (transcribed by the third author) and the questionnaire answers were analysed by two coders, namely, the third and the first authors. Firstly, the two coders assembled an overview of all the statements describing factors enabling student learning, in the form of Excel spreadsheets. This overview included all factors mentioned that enabled learning, with no distinction between factors already in place or those that could be implemented to enable learning.

Secondly, the two coders progressively selected random samples of statements from the overview and interpreted and ordered the statements within and across the learning environment components (i.e. *people*, *pedagogies*, *structures* and *processes*) already introduced in the conceptual background section. While in a few cases, a statement could be related only to a single component, in many other cases a statement could be related to multiple components at once. After these statements were ordered within and across educational components, they were coded by the two coders. Each given code represented an enabler, or in other words a feature of the learning environment that affected other features and ultimately contributed to students' SoL. More samples of statements were added gradually in the analysis, until all statements were interpreted, ordered and coded. In this process, the two coders periodically discussed their assigned codes and the different interpretations sometimes arose when coding the statements, thus arriving at consensus about the final enablers. Furthermore, the two coders consulted the literature to guide the definition of those enablers (the main literature used is indicated in the next section).

This process led to the definition of six intertwined enablers, which are described in the next section, positioned within and across the learning environment components. Note that each identified enabler represents statements connected to two or more components as expressed by three or more categories of respondents (students, commissioners, coaches, teachers, advisors and brokers). As an additional step to verify the appropriateness of the identified enablers, we approached 26 students, each of whom had been the "manager" and representative of one of the student teams enrolled in the course during a different eight-week period. These students filled in an open-response questionnaire containing the same guiding question used for the focus groups in the period under investigation (see subsection 3.1). The questionnaire answers, as inspected by the first and third authors, confirmed the previously identified enablers and did not reveal new insights.

Third, to ensure the validity and quality of this case study research, the "audit method" was implemented, based on Akkerman *et al.* (2008). The audit method is a validation procedure particularly suited to quality judgement within complex research processes involving interpretations and iterations. The audit procedure concerns a trajectory in which the "auditees" (i.e. the third and first authors running the data analysis) engage an "auditor" (i.e. an educational scientist) to perform the audit and evaluate the quality of the auditees' work. During a first orientation meeting, the two auditees introduced the research scope and research steps to the auditor and agreed with the auditor on the audit tasks and procedure. The two auditees prepared an audit trial report containing all background information on the study and the analysis done, including the raw data, the processed data, the coding book and the results.

The auditor then used the audit trial report to evaluate the quality of the study. The auditor confirmed the alignment between research aim, context, conceptual background, research approach, research methods and findings. The auditor also confirmed that the

findings and concluding remarks were visibly grounded in the process of data gathering and analysis (visibility), were well substantiated (comprehensibility) and logically and scientifically acceptable (acceptability). Additionally, the auditor provided comments aimed at strengthening the presentation of the study design and the methods for data analysis. Those comments were integrated into the study. After the whole auditing procedure was completed, the first author invited the auditor to join the team of co-authors (the auditor is now listed as second author). Furthermore, the fourth author, an educational scientist within the field of education for sustainability, was invited to join the team of co-authors by providing reflections throughout the development of the paper.

Finally, interviews were held by the first author with four WUR educators in charge of the educational design and implementation of four other transdisciplinary, academic consultancy and sustainability-oriented WUR courses (each of these courses involves about 80 to 240 students per year). During those individual interviews, the educators were informed of the findings of this study, after which they were invited to reflect on the potential relevance of the identified configuration of enablers. Their reflections were written down by the first author during the interview, read and then validated by each educator at the end of each interview. All educators confirmed the relevance of the configuration presented. Their reflections are integrated in the discussion section of this paper. Finally, the study findings were presented to the ACT community by means of two workshops (with 42 attendees) led by the first author. The workshop participants were invited to reflect on the identified configuration of enablers. Some of those reflections are outlined in the discussion section as well.

4. Findings

Based on the analysis described in the preceding section, this study identified an interplay of six enablers. Those six features, positioned within and across the components of the learning environment, are: *capacities of university and societal stakeholders (people)*; *emancipatory pedagogy and instructive pedagogy (pedagogies)*; *brokering arrangements and course attributes (structures)*; *students' learning processes (processes)*. Altogether, these enablers make up an organic learning system contributing to students' SoL in this case study, based on the *meaning-making* of the study participants. Figure 3 presents those enablers as a situated configuration enabling SoL. The interrelated nature of the enablers is indicated explicitly by the dotted lines.

These six enablers emerging as critical to the ACT learning system interact with each other and within and across the course components, and science and society, as evidenced by the analysis of the participants' statements. Together, these interrelated enablers help cultivate learning in the sustainability-oriented course landscape. Table 1 describes each of the six enablers, based on what emerges from this study, and makes reference to literature supporting their articulation. Furthermore, this section elaborates on each of those enablers and on their intertwined character by drawing on the analysis of the focus groups and questionnaire data. In the attempt to give personal meaning to this elaboration and a sense of how each enabler is enacted in day-to-day educational practices, the voice of the participants is represented by sharing certain statements which are illustrative of their experiences and views throughout the course. Those few illustrative statements are not meant to be fully representative of the data set and of the interrelated character of each enabler. They simply aim to give a tangible sense of the perceptions of the course participants.

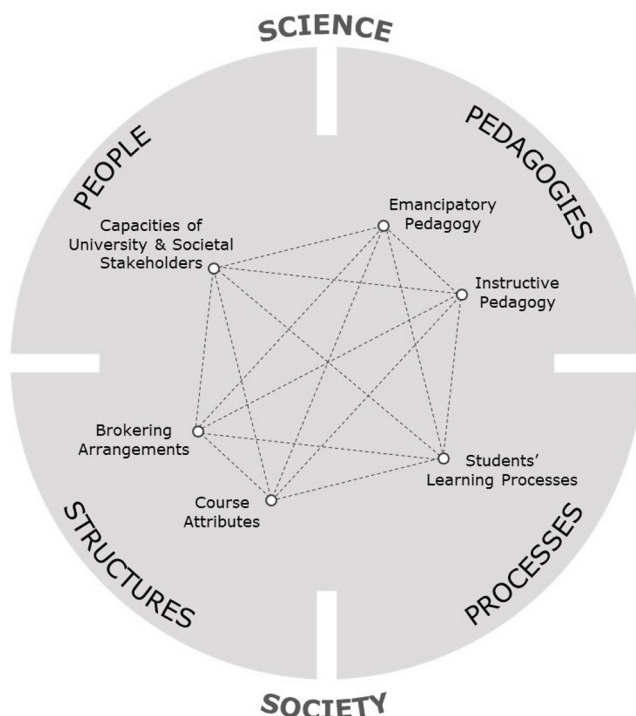


Figure 3.
Configuration of six
SoL enablers

4.1 Capacities of university and societal stakeholders

Findings indicated that the capacities of both the university staff and the societal stakeholders have a crucial role in the learning system and in enabling students' SoL in the course under exploration. Well-equipped staff and members of society adopted an *emancipatory pedagogy* style and engaged with students in a participatory fashion; adopted an *instructive pedagogy* style by taking a more directly instructive approach and providing students with possible correct ways forward; or switched back and forth between these two styles in accordance with the project demands and students' learning needs. Structural course components such as *course attributes* and *brokering arrangements* played a role as well in the engagement of the various ACT stakeholders. The use of learning materials, for example, supported the staff in guiding the students. Similarly, the general project description defined at the start by brokers and commissioners provided an initial orientation about the project for students and for the university stakeholders involved.

Moreover, the analysis showed that the engagement of *university and societal stakeholders* also depended on the capacities that the people involved already had or lacked. These capacities, or the lack thereof, in turn affected *students' learning processes*. When equipped with suitable capacities, the coaches, teachers and the others involved boosted the *students' learning processes* in multiple ways. For example, these stakeholders provided students with insights into how to build "relationships of quality"; encouraged students to communicate a different viewpoint and work in a "boundary-crossing" fashion; and so on. In other cases, difficulties were encountered. For example, a coach shared the following:

Component	Enabler	Description
People	► Capacities of university and societal stakeholders	This is about engaging well-equipped university staff and societal stakeholders and, when appropriate, developing their capabilities through capacity building activities (Di Giulio and Defla, 2017)
Pedagogies	► Emancipatory pedagogy	This is about generating space for reflexivity and choices, both freely made and self- or group-determined, with the intent to empower students to shape the direction of their collaborative work in the midst of challenges (Wals and Jickling, 2002)
	► Instructional pedagogy	This is about transferring course procedures, standards and knowledge to students, with the intent to support students' collaborative work in a specific pre-established direction (Wals and Jickling, 2002)
Structures	► Brokering arrangements	This is about ensuring the recruitment of transdisciplinary sustainability-oriented projects, as well as the formation of the team of students and the matching of students' academic backgrounds to the respective projects (McMillan et al., 2016)
	► Course attributes	This is about implementing course materials, activities, assessment, schedule and time arrangements that are aligned with the aim of the course (van den Akker, 2004)
Processes	► Students' learning processes	This is about nurturing relationships of quality, role identities, boundary-crossing, agency and responsiveness, academic consultancy and ethics (Akkerman and Bakker, 2011; Tassone et al., 2018; Burke and Stets, 2009)

Table 1.
Six SoL enablers

How do you coach students in multi-perspective problem analysis? That is not so obvious. How do you bridge those perspectives when they are so diverse?

Such difficulties faced by ACT staff and stakeholders could be tackled through capacity building activities, which would enable these people to sharpen their abilities and properly support students. Respondents suggested that this could entail, for example, periodic workshops led by university staff or a guest expert that focussed on a relevant coaching/teaching/advisory topic. Other possibilities mentioned were a buddy system and learning circles fostering the sharing of knowledge and experiences.

4.2 Emancipatory pedagogy

Emancipatory pedagogy was identified as another important interrelated enabler, focussed on empowering students to be in charge amid the challenges which can arise in complex learning environments. The *capacities of university and societal stakeholders* and their engagement as critical friends contributed to the embedding of such pedagogy. For example, a coach made this remark about the emancipatory approach adopted with the students that were facing some challenges:

I say: welcome to the real world. I am not going to solve this for you [. . .]. And that is one moment that always appears at the start, and if they find their way out of it, I feel proud of them as a coach.

Emancipatory pedagogy also took shape through the implementation of *course attributes*. This type of pedagogy manifested in a number of ways, for example, learning activities

supporting experiential learning, feedback sessions focussed on boosting students' reflexivity or learning materials such as handouts for empowering student decision-making. This pedagogy also informed *brokering arrangements*, especially by making sure that the project description students received at the start of the course was open enough to let students bring their own perspectives to the research they were undertaking to address the given sustainability challenge.

The findings indicated that this pedagogy empowered *students' learning processes*. Students learned to shape their own path instead of being spoon-fed with answers and to manifest their "agency and responsiveness"; they felt stimulated to gain awareness of their "role identities" and to take up the role of academic consultants while being students.

4.3 Instructive pedagogy

The implementation of *instructive pedagogy* also emerged as another crucial feature enabling student learning. Suitable *capacities of university and societal stakeholders* were needed to give shape to this type of pedagogy, for example through the transmission of academic or practical expert-driven knowledge, the transfer of the course *modus operandi* and the directions provided by the ACT staff enabling students to meet the standards of the course.

The presence of *instructive pedagogy* was reflected by *course brokering arrangements*, such as a well-defined description of the challenges faced by the commissioner and the provision of commissioners' resources, which gave direction to the project. This pedagogy was facilitated through *course attributes* as well. The study material stating procedures and instructive steps, assessment standards and deadlines to be fulfilled were an expression of an instructive pedagogy style, giving direction to student learning. For example, a student highlighted the usefulness of having instructive study material as follows:

With everyone coming from different backgrounds, having different approaches towards writing a proposal [...]. I think this handbook really gives structure and I think that has really helped us in structuring our work.

According to the data analysis, *students' learning processes* were constructively shaped through this pedagogical approach. Students needed directive guidance at times, and when they received it, they felt supported when dealing with uncertainties and had the courage to avoid taking shortcuts in their "academic consultancy and ethics" processes.

4.4 Brokering arrangements

Brokering arrangements, performed in this case study by university brokers, emerged as another feature that added value to the learning system. The analysis of the collected data suggested that, as part of the brokering process, it was important to hold *a priori* discussions with commissioners about the transdisciplinary nature of the students' endeavours. The ACT research endeavour required commissioners to have the *capacities* to be open to different perspectives and disciplines, and to bring forward a project challenge that welcomed the integration of multiple vantage points.

Furthermore, findings indicated the relevance of a well-prepared project description, created by brokers and commissioners, and which students read at the very start to orientate them to their work. It was appreciated when the project description reflected both *instructive pedagogy* (e.g. providing relevant literature to consider at the outset) and *emancipatory pedagogy* (e.g. not defining the methodological research steps in advance).

In the brokering phase, it was also appropriate for brokers to discuss specific projects needs with the commissioner that could be tackled by means of *course attributes*. For example, to address the need for high confidentiality of project information, structural

course documents and contracts could be used to provide formal support on how to properly handle confidential information. It was considered helpful to carefully select students to create a team whose disciplinary expertise matched the transdisciplinary project focus. This influenced the *students' learning processes* in multiple ways: it helped students to experiment with “boundary-crossing” and to bridge diverse scientific and cultural perspectives and boosted students’ “agency and responsiveness”, as they were able to make use of their expertise to address complex sustainability problems. For example, a broker reflected on the students’ engagement as follows:

It excites them that they are working on a project that they feel they are an expert about, and that they can help to find answers to the questions or problems. And if the project does not fit their expertise, they might not feel as confident that they can work on it.

4.5 Course attributes

The *course attributes* were identified as another interrelated enabler supporting student learning. The provision of learning materials was perceived as a relevant part of the *course attributes*. Several learning resources were deemed significant: the course guide, which provided insights on what to learn in the course and how to do so; the handbook, which guided the development of a transdisciplinary proposal and output; and the study material, which guided the interpersonal reflections of the students. Such material embedded *emancipatory pedagogy* in some cases and *instructive pedagogy* in others, provided guidance to students and supported the engagement and *capacities of university and societal stakeholders*.

The same goes for a variety of learning activities, which included team building, multi-perspective research activities and arts-based and ethical reflections. Together with the learning material, the learning activities positively supported *students' learning processes*. Students were given the tools to reflect upon their “role identities”, to experiment with stepping into the role of academic consultant in a safe educational space and to engage in “academic consultancy and ethics” processes in response to the sustainability challenge at hand.

Furthermore, having a schedule with set deadlines throughout the course also appeared to support students in organising their work and monitoring their progress. For example, it was helpful for students, to announce a submission deadline for a reflection paper or for their outputs. Another relevant attribute was the assessment of the students’ work and the criteria related to assessing its quality. Findings revealed that the possible conflicts between assessment criteria should be either avoided or there should be suggestions about how to navigate conflicting objectives, to positively impact *students' learning processes*. For example, stating “independence” as an assessment criterion created a conflict with the criterion “transdisciplinary collaboration”. As explained by a student, the focus on independence made students hesitant to engage in “boundary-crossing”, to ask for feedback and to collaborate with other parties:

We are being graded on the independence of our team, on whether we are doing the job on our own. That's why we are hesitant to go ask for extra feedback or advice, or to go to the commissioner or whatever.

4.6 Students' learning processes

Cultivating *students' learning processes* at a personal, collaborative and content level was also recognised as a crucial enabler of SoL. These processes focussed on nurturing

“relationships of quality”, “boundary-crossing” capacities, “agency and responsiveness”, “role identities” and “academic consultancy and ethics”. This section briefly introduces these processes and provides a few examples of how they are related to other enablers. Creating “relationships of quality” among students and with other parties, based on trust and respect for differences, was depicted as a foundation of the students’ SoL. For example, when reflecting on the team activities as part of *course attributes* and in connection to the student’s team “boundary-crossing” efforts, a student reflected as follows on the relevance of creating trusting relationships:

Our group has three entomologists and three nutritionists; the project combines the two disciplines. Culturally speaking, three Italians and three Dutch [...]. Personally I’m a chaotic person, but I’m very creative. And my partner on the job, he’s really structured. We combine my creativity and his structure and we create a very nice output. But this is based on respect for each other, for each other’s culture and background, and trust.

One other relevant process concerned developing awareness of “role identities”. By means of various *course attributes*, students reflected on their role and identity and were stimulated to see themselves as academic consultants in an educational setting, not just as students. Furthermore, “boundary-crossing” was another crucial process which engaged students in becoming conscious of different disciplinary and cultural perspectives, in communicating and expanding their own perspectives by acknowledging those of others and in handling differences and integrating perspectives in a transdisciplinary fashion. This was considered a very delicate process, requiring the engagement of suitable *capacities of university and social stakeholders*. Students also engaged in processes of “agency and responsiveness”. This entailed bringing forward an idea, initiating a course of action and responding to emergent needs by identifying new ways forward.

Finally, “academic consultancy and ethics” also emerged as a crucial process. Students learned to perform academic research in a consultancy-like fashion and to engage creatively, critically and ethically in responsibly addressing a sustainability challenge in society. The enactment of *emancipatory* and/or *instructive pedagogy* supported this process, in combination with various *course attributes*. For example, as communicated by brokers when reflecting on both learning materials and activities:

The handbook included ethics. We encourage students to reflect on that. Students themselves may have to reflect on ethical dilemmas even if the commissioner did not require that.

5. Discussion

When reflecting on the findings elucidated above, and the research that underlies them, several implications for educational research and practice emerge.

This study adopted an eco-social system perspective and explored the relation across *people, structures, pedagogies* and *processes* within a transdisciplinary learning environment, based on the *meaning-making* of those involved in that environment. Our findings indicate that this perspective can offer a valid and generative approach for understanding educational efforts from a more relational and ecological perspective. In this study, this approach has led to the development of a situated configuration of interrelated enablers of learning in a transdisciplinary academic consultancy course. Similarly, this relational approach can assist other researchers and educators searching for more integrative ways to explore enablers of learning and to develop system thinking (Sterling, 2004).

Furthermore, the mapped SoL configuration of interrelated enablers can offer a basis for meta-level reflection and dialogue among educators and stakeholders. All four interviewed

educators who were involved in other transdisciplinary and sustainability-oriented WUR courses than the ACT course (see analysis section) indicated that they derived insights from seeing the configuration containing those overarching enablers. They said they recognised those enablers as relevant features of their courses as well. This suggests that the configuration developed here can generate so-called “aha” moments of insight (Irvine, 2015) that can help educators, like the ones interviewed, to recognise current aspects of their courses and structure them. The interviewed educators also acknowledged the potential usefulness of those interconnected enablers as prompts, when entering into a dialogue with other educators and stakeholders for reflecting upon and for designing or revising courses with a system-thinking mindset. Similarly, the enablers can be useful for educational peer review processes to discuss, in an integrative way, key features of transdisciplinary courses.

The relevance of the identified SoL configuration of enablers for stimulating meta-level reflections and dialogue was also confirmed by the reflections of the ACT community who took part in two workshops to discuss the study findings (as mentioned above in the analysis section). During the workshop, it was indicated that the identified configuration of intertwined enablers helped in providing a broad overview, which can easily be overlooked in complex learning environments engaging large numbers of people performing different tasks at different moments. To take one example, communicating about the *brokering arrangements* was an eye-opener for students and stakeholders not directly involved in those arrangements. The students realised that the project description provided at the start was not fully pre-defined, not because of any deficiency in the set-up, but because this gave them the opportunity to co-develop the direction of the project. Knowing this also helped staff to understand the *emancipatory pedagogy* underlining this arrangement and monitor to what extent students could cope with this. When more direction was necessary, it also served to support *students' learning processes*.

Additionally, by mapping a situated configuration of enablers fostering students' SoL based on the *meaning-making* of all those involved in it, this study suggests that SoL is more than the sum of its enablers. While the findings made evident that the configuration of the identified enablers did generally support student learning in the given course context, the findings also showed that things that promote learning in one particular student or team might be less appropriate for another student or team. For example, while *emancipatory pedagogy* was more relevant in one case, *instructive pedagogy* was more relevant in another. Support for students' SoL depends not only on the interactions across features of the learning system. It also depends on the ability to see and to respond to the learning needs of the students and all those involved and to decide accordingly what enablers need to be activated and how. As suggested by Wals (2019), this situated understanding of SoL calls for “continuous sense making, contextualization, recontextualization and recalibration” about what is relevant in a certain context at a certain moment for a certain student (p.62). This challenge invites educators and stakeholders to focus on the importance of the present moment, to be caring, to be attentive and to be responsive (Tronto, 2013) towards emergent needs of the students and those involved within the educational context in which they are situated.

The authors acknowledge that this study has not considered possible other influences (e.g. social, institutional and personal life) that can also play a role in student learning (Jackson, 2020). Furthermore, findings are based on specific methods (focus groups and questionnaires) and do not consider the possible relative importance of the identified enablers. Additionally, although findings were considered relevant by interviewed educators external to the case study and by the ACT community consulted, those findings were nonetheless related to one specific university academic consultancy transdisciplinary course. Future studies can help to confirm or enrich the findings of this study by investigating the potential role of additional influences, using a richer variety of data

collection methods (e.g. observations), engaging in more detailed analysis (e.g. further qualifying or even quantifying the interrelationships about the enablers) and investigating other course contexts.

6. Conclusion

This study explored what enables students' SoL in a university-wide transdisciplinary course context at the interface of science and society. By means of an eco-social system perspective, the study mapped a situated configuration of interwoven features enabling students' SoL, based on the *meaning-making* of students, university and societal stakeholders engaged in the course. The identified configuration can offer inspiration and guidance to educational researchers and practitioners in at least three ways.

Firstly, this study suggests that adopting an eco-social systems perspective, instead of considering single features only, is a valid and generative approach to map what enables students' SoL when considering interconnections and interdependencies in a given learning environment. Secondly, the mapped SoL configuration of interrelated enablers could be used as a heuristic for supporting system-based reflections and dialogue across educators and stakeholders, e.g. for designing or re-designing SoL courses at the crossroads between academia and society, and as part of educational peer review processes. Thirdly, this study makes explicit that SoL is more than the sum of its enablers. In fact, cultivating SoL also requires educators and stakeholders to be fully present - in the "here and now" -, to cultivate the moral qualities of being attentive and responsive to the learning needs of the students and all those involved and to decide accordingly what enablers to activate in a certain context at a certain moment for a certain student.

Ultimately, this study shows that adopting a relational, situated and system-based approach is feasible, and it is also desirable for nurturing student learning in complex environments.

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About the authors

Valentina C. Tassone is an Assistant Professor at Wageningen University. Her research focuses on sustainability-oriented education and deep learning. Her studies take place in the context of (higher) education, community setting or society at large and often at their crossroads. Valentina C. Tassone is the corresponding author and can be contacted at: valentina.tassone@wur.nl

Perry den Brok is the Chair and Full Professor in Education and Learning Sciences at Wageningen University. He is also Chair of the 4TU Centre for Engineering Education, an educational innovation centre of the four universities of technology in the Netherlands. His research interest lies in the domain of educational innovation in higher education, learning environments research, teacher learning and professional development.

Cassandra W.S. Tho is a Junior Researcher in Education and Learning Sciences at Wageningen University. Her research interests lie in the domain of educational innovation in higher education, with a focus on boundary crossing and challenge based learning.

Arjen E.J. Wals is a Professor of Transformative Learning for Socio-Ecological Sustainability at Wageningen University where he also holds the UNESCO Chair of Social Learning and Sustainable Development. Furthermore, he is a Guest Professor at the Norwegian University for the Life Sciences (NMBU). His work focusses on enabling, supporting and assessing ecologies of learning that foster sustainable living by inviting more relational, ethical and critical ways of knowing and being.

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