Cultivating learning in the transdisciplinary-oriented Academic Consultancy Training

A research study report

WAGENINGEN UNIVERSITY & RESEARCH

ENTRANCE

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Cultivating learning in the transdisciplinary-oriented Academic Consultancy Training
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Summary

This research study explores what affects, and helps to cultivate, *transdisciplinary-oriented learning* in the Academic Consultancy Training (*ACT*) course. ACT is a Master of Science course at Wageningen University (WU). The study presented here is part of an ongoing process of innovation with a focus on boosting students' transdisciplinary-oriented learning. ACT engages collaboratively teams of WU students from diverse disciplinary backgrounds, and WU staff and societal actors, to respond to real-life complex societal challenges. This research investigates the perceptions and experiences, with regard to students' transdisciplinary-oriented learning, of over 100 WU students, WU staff and societal actors engaged in the course and its on-going innovation. It is a qualitative study grounded on an action research approach. Drawing from in-depth focus groups and open-ended questionnaire, the data is elaborated through thematic analysis.

ACT is regarded here as an *eco-social system.* As such, ACT educational components and mechanisms playing a role in learning are considered in systemic interaction with each other. This study has identified four fundamental interconnected *educational components* affecting students' transdisciplinary-oriented learning: the ACT *pedagogy* (the approach in teaching and facilitating), the ACT *structure* (the means constituting the structure of the course), the ACT *process* (the aspects affecting learning at a personal, collaborative, content and output level), the ACT *community* (the people engaged in the course). Those components, and related identified sub-components, interact with each other and activate *learning mechanisms* that affect transdisciplinary-oriented learning. Insights about those interconnected educational (sub-)components and learning mechanisms are discussed in details in this report. Those insights make clear that the on-going ACT innovation is well enabling students' transdisciplinary-oriented learning through multiple mechanisms, and that there are also hindering mechanisms that challenge learning, and that need attention.

Furthermore, the study distils 7 learning mechanisms, called learning drivers, that tend to accelerate students' transdisciplinary-oriented learning.
Those *7 learning drivers* are:

1. Have transdisciplinary projects matching the teams
2. Empower students to be in charge in the midst of challenges
3. Transfer course procedures and standards
4. Build trust and constructive relationships
5. Enable students to navigate & integrate multiple perspective
6. Handle time constraints
7. Embed staff circular learning communities

When they are in place, those drivers not only reinforce learning, but they also help addressing learning challenges. In this sense, those drivers can be seen as fundamental conditions, that tend to create positive chain of effects boosting transdisciplinary-oriented learning across the ACT eco-social system. As such, those drivers can inform the educational innovation practices of ACT staff and can guide future choices for further cultivating ACT students' transdisciplinary-oriented learning.

This study is supported by the WUR course innovation fund, the European Union ENtRANCE project, and the 4TU Centre for Engineering Education.

1 Aim and background

The aim of this research study is to explore what affects, and helps cultivating, transdisciplinary-oriented learning in the Academic Consultancy Training (ACT) course, based on the views of those engaged in the course. The study is supported by the WU course innovation fund, the European Union ENtRANCE project, and the 4TU Centre for Engineering Education.

ACT is a capstone Master of Science course at Wageningen University (WU), undergoing a process of innovation. The ACT course design is transdisciplinary-oriented, in the sense that ACT by design engages collaboratively teams of WU students from diverse disciplinary backgrounds, and academic and societal actors, to respond to real-life complex societal challenges. Based on the feedback of the ACT students and the other actors engaged in the course and on the scrutiny of the course evaluations, the need emerged to innovate aspects of the ACT education (e.g. educational strategies, teaching materials, learning activities, etc.) in order to more explicitly foster transdisciplinary-oriented forms of learning, in line with the given ACT course design.

Elsewhere, research findings (Di Giulio & Defila, 2017) suggests too that complex transdisciplinary environments need to be coupled to matching educational strategies, activities, etc. in order to best support transdisciplinary learning. Similarly, empirical findings (Cremers, 2016) point out that in complex hybrid learning environments, like the ACT ones, learning can remain implicit and students may not even realize they are learning more complex and transdisciplinary skills, when this is not explicitly fostered through matching educational strategies, activities, etc.

This study explores, through an action research approach, the experiences and perceptions of communities of students, commissioners, and staff (teachers, coaches, academic advisors and knowledge brokers) engaged in the ACT course and its on-going innovation. Based on the views of those communities, which compose all together the *ACT community,* this study distils *educational (sub-)components* and *mechanisms* that affect students' transdisciplinary-oriented learning, by enabling it or hindering it. It also distils *drivers* that tend to accelerate such learning.

The findings of this study can help directing the educational innovation efforts of the ACT staff, and can inform future choices for further cultivating transdisciplinary-oriented learning.

2 Context

2.1 The ACT course

The ACT course represents the underlying research context in this study. ACT is a 9 ECTS course that is offered all year round, every two months. It engages every year almost 1,000 WU students from 19 diverse study programs, about 150 societal commissioners, and over 100 WU staff people. Some staff people contribute to ACT all year round, while others work only in certain periods of the year.

The ACT transdisciplinary-oriented design is depicted in Figure 1. ACT engages teams, each of about six students from diverse disciplinary (and often cultural) backgrounds, to respond to complex real-life societal challenges faced by organizations in society and within the WU domain of food and living environment. Those organizations in society, called *commissioners*, are governmental, business, and civil society organizations. In collaboration with those commissioners and based on their real-life challenges, the ACT staff of WU *knowledge brokers* create projects upon which ACT *student teams* work. Each ACT student team works on one of those projects, in between academia-society, for a total of 8 weeks.

In the first 4 weeks, each ACT team collaboratively develops a project proposal by putting together academic and practical knowledge. The team defines, in collaboration with the commissioner, underlying project challenge, project goals, research questions, methods of research and analysis, planned activities and outputs. In the following 4 weeks, each team collaboratively execute the proposal and provide an integrative, scientifically sound and practically relevant advice on how to possibly respond to the challenge at hand. The ACT staff of WU *academic advisors*, *coaches* and *teachers*, support the students' endeavours. The staff supports project content development, students' team-building processes, as well as professional and personal process development, based on students' needs. Overall, the *ACT coordination team* is responsible for the whole ACT design, innovation and implementation, and it acts as course catalyser and as bridge-maker across the various communities of students, staff and societal commissioners.

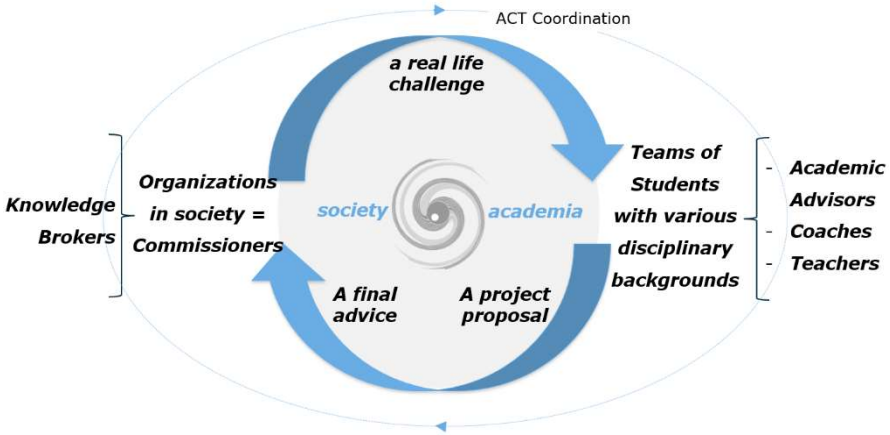

Figure 1. The ACT transdisciplinary-oriented design

2.2 Innovation in the ACT course

With the intent to explicitly support ACT students' transdisciplinary-oriented learning, in line with the ACT course design, an innovation of the course was initiated. This innovation process was guided by few steps. Firstly, the notion of transdisciplinarity in ACT was discussed with representatives of the various communities, and then described, drawing from literature. While each ACT real-life project challenge and related collaborative process has its own characteristics, overall ACT can be especially described as a form of "consulting transdisciplinarity" (Mobjörk, 2010). That is: "the ACT student teams are responsible for collaboratively exploring, applying and unifying academic and practical knowledge, in order to jointly provide an academic consultancy advice for addressing a societal challenge. The ACT staff is part of this collaborative endeavour by bringing in academic knowledge and by supporting the students' development and learning, while the commissioners bring in their practical knowledge and needs to be integrated".

Secondly, a literature study was conducted, to better understand the implications for learning in complex transdisciplinary environments and, in turn, to guide the renewal of ACT education. Insights were drawn from Polk (2015) and Lang et al. (2012) to understand principles for collaborative knowledge production in between academia and society; from Schauppenlehner and Penker (2015) to understand collaborative group processes in transdisciplinary contexts; from Gulikers and Oonk (2016) to understand assessment criteria for evaluating boundary crossing processes; from Di Giulio and Defila (2017) to understand the relevance of enabling university staff to foster students' transdisciplinary learning.

Thirdly, based on the above efforts and in discussion with people from the various communities, changes were gradually introduced in the course, including:

- Renewal of course guidelines and learning outcomes, with a focus on communicating more explicitly the transdisciplinary-oriented character of ACT and the ACT transdisciplinary learning process.
- Renewal of course materials, teaching and learning activities and assessment strategies, especially concerning a more explicit focus, guidance (through learning material and activities) and assessment on:
    i) the development of an integrative project purpose definition, research questions and an overall transdisciplinary project proposal (to be delivered in the 4th week of ACT), bringing together multiple disciplinary and practical objectives, and constituting the base for the integrative ACT final advice (to be delivered as end-product in the 8th week of ACT);
    ii) the development of the students' capacities to work as academic consultants in-between academia and society, and specifically in terms of cross-boundary awareness, communication and collaboration capacities.
- Development of support on-demand for ACT staff, i.e. coaches can receive (upon request) support from an expert for further sharpening their capabilities for coaching students throughout their ACT transdisciplinary-oriented academic consultancy proposal development and implementation work.

This innovation took place gradually throughout *three consecutive spiralling cycles* (i.e. every two months for a total of three consecutive times/cycles). The students, commissioners and staff involved engaged in rounds of reflections and actions throughout those three cycles. Those people were experimenting in practice with the innovative aspects introduced in the course and, by taking up a researcher attitude, they were reflecting on the implementation of the innovation in order to further improve the practice. The study presented here was conducted *in the third cycle* with the intent to capture the views of the people engaged and to identify what enables, what hinders, and what can boost transdisciplinary-oriented learning. In turn, those insights can further inform ACT staff educational practices, and can guide future ACT innovation.

3 Conceptual background

In order to explore what affects and helps cultivating students' learning in the transdisciplinary-oriented ACT, a *systemic* approach is taken. ACT is regarded as an ecosystem. More specifically, it is regarded as an *eco-social system* made up of components potentially affecting each other, and defined according to the meaning-making of the various engaged people, part of the overall ACT community.

The concept 'ecosystem' is introduced in literature in the early 1930s (Willis, 1997; Tansley, 1935). Since then, the concept has been extensively elaborated, also to denote an ecological system constituted by interconnected living components and non-living components. Nowadays, the term 'ecosystem' is also used as a metaphor to describe complex interconnected environments, for example educational environments. Educational ecosystems are constituted by various people like students, teachers, stakeholders, etc. (*the living components*), various things or means like educational activities, materials, resources, etc. (*the non-living components*) and their dynamic relation within an educational environment (e.g. den Brok, 2018; Mueller and Toutain, 2015).

By further transferring the notion of ecosystem into a human and social educational context, and drawing from classical systems theory, Lemke (1997, 2000, 2006) discusses the notion of *eco-social system*. What is peculiar about an eco-social system, amongst other ecosystems, is that it does not only concerns people and things, but also *processes*. Eco-social systems are thus also defined in terms of their processes. In this sense, processes can be as well regarded as a crucial component of the system. Additionally, the overall dynamic of the eco-social system as a whole does not depend only on what the various components do with each other, but also on what those doings *mean* to people (Lemke, 1997). It is through participation in what Lemke (1997) calls "micro-ecologies" of situated practices with other people, things, and processes, that meanings are formed. Within such situated practices, based on people's experiences and perceptions, background and positionality in a specific context, people can define what they value, what they consider supportive for learning, what they see as challenging, etc.

The systemic and situated nature of education and learning is discussed for example: by Lave and Wenger (1991) exploring the contextual nature of learning within communities of practices; by Jackson (2016) framing people's personal experiences within an ecological paradigm in relation to life-wide learning; by Wals (2019) describing ecologies of learning for sustainability as blended learning configurations; by Barnett (2018) introducing the idea of the ecological university as a complex interconnected environment.

In this study, by drawing on those concepts, ACT is envisioned as an eco-social system. As such, this study explores educational living, non-living, process (sub-)components and related mechanisms that play a role in students' transdisciplinary-oriented learning, based on the meaning-making of those organically engaged in the ACT innovative practices. In line with epistemological pluralism (Miller et al., 2008), this study overall considers that there are different valuable ways of knowing, vantage points and (learning) needs of the ACT community people engaged and that accommodating this plurality can lead to a comprehensive and integrated study.

4 Research approach and methods

4.1 Research approach

This study, and the overall ACT spiralling innovation efforts of which this study is part, takes an *action research* approach (Reason and Bradbury 2006). Action research is rooted in a participatory worldview and focuses on producing knowledge while experimenting with concrete actions in a certain context. Such an approach is considered relevant in transdisciplinary environments, as it allows for the generative combination of multiple forms of knowledge about what can and should be done for creating change and transformation, while acting on it (Peter and Wals, 2013). Action research is appropriate for this study because it can help developing multiple and situated ways of knowing based on the meaning-making of the ACT people, and drawing from their concrete experiences and challenges. Also, adopting an action research approach implies innovating the course *with* the ACT community, instead of *for* the ACT community. The views of students, staff and commissioners on the topic of what educational aspects play a role in cultivating students' transdisciplinary-oriented learning, were explored by means of *focus group* conversations and of open-response *questionnaires*. The focus groups as well as the distribution of the questionnaires, took place in the second half (in the last four weeks) of the third cycle of ACT innovation. The ACT coordinators were engaged as catalysers of this research study and as (co-)researchers. Consequently, ACT coordinators were not participants of the focus groups and questionnaires.

4.2 Methods for data collection

The *focus group* method (e.g. Krueger and Casey, 2015) was implemented to explore the views of the students, coaches, teachers and knowledge brokers engaged throughout the third cycle of ACT innovation. The focus groups were designed and implemented based on a socio-constructivist perspective (Ryan et al, 2014). From this perspective, focus groups are seen as a dynamic social process where participants can relationally explore their views about learning, within a group dynamics (Ryan et al, 2014). One's experiences, perceptions and overall meaning-making can then be shared, further shaped and constructed through dialogic interaction with others. In other words, the focus groups enable participants to share views on learning as a result of their participation and interaction within the ACT eco-social system. The application of focus groups is suited in this study because it allows for an interplay of diverse personal views on the topic and the possible creation of new shared meanings. In the focus groups, an *interview style* (providing guiding questions) was mixed with a *dialogic style* (fostering a dialogue). A total of 33 students (representing 198 students, i.e. each student is the representative of one of the 33 student teams), 27 coaches that were coaching all students' teams involved (some coaches were coaching two student teams), 5 teachers and 5 knowledge brokers involved were invited and participated in a focus group. In sum 10 focus groups were conducted, each of about one hour, and each with a minimum of 5 and a maximum of 10 participants. Each focus group included only people from the same type of respondents, so for example a focus group with students did not include coaches, teachers, etc.

The focus group conversations were implemented through a loosely structured protocol, and were facilitated by the authors. The transdisciplinary-oriented character of ACT was briefly introduced and ACT was described especially as a form of "consulting transdisciplinarity" (Mobjörk, 2010), as already explained earlier. This brief introduction was meant to provide an initial common ground for further conversation. Then, *two leading open-ended questions* (*interview style*) were introduced: 1. what educational aspects enable transdisciplinary-oriented students' learning? and 2. what educational aspects challenge or hinder such learning. Based on those questions and by means of a dialogue (e.g. Bohm, 1996; Freire 1974; Scharmer, 2016), the participants of the focus group shared their personal views, with the possibility to build on each other's comments, present alternative views, trigger a further inquiry, and let even emerge a new understanding of the topic (*dialogic style*). The focus groups conversations were videotaped (with permission of all participants) and then transcribed.

Furthermore, an open-response *questionnaire* was used as an additional method to explore the views of the commissioners and academic advisors. The questionnaire was conducted online by means of Qualtrics (www.qualtrics.com). A link to the online questionnaire was sent individually to the 33 academic advisors and 33 commissioners. The use of a questionnaire was pertinent in this case, given the impossibility of organizing focus groups within a short time frame at fixed dates with commissioners located in different regions of the world, and with academic advisors engaged in ACT within a very tight schedule and often abroad for work. The online questionnaire included the same two leading open-ended questions used in the focus groups. Participants were asked to individually address the open-ended questions and share their views. A total of 15 academic advisors and 17 commissioners responded and provided their answers.

4.3 Methods for data analysis

The data collected was elaborated by means of a *thematic analysis* (Boyatzis, 1998). The transcribed focus groups data and the open-ended questionnaire data were organized into interconnected *themes (and related sub-themes).* The themes (and sub-themes) captured, within and across the data available, repeated patterns of meaning describing educational components, sub-components and related mechanisms that enabled or hindered students' learning in a transdisciplinary setting. There were also suggestions provided on what could further enable learning. The ACT educational components (= the themes), and the educational sub-components (= the sub-themes within each theme), were defined and organized in an iterative manner based on what emerged from the data and supported by what was known from literature.

In order to ensure *reliability*, the selection of those ACT educational components and sub- components was performed in *four rounds.* These four rounds of analysis were conducted by both the first and second author, with the second author being the main coder of the full data set. It should be noted that statements of exclusion, in the form of rules for encoding the data (= the text describing the perceptions and experiences of the ACT communities) only within one certain component and/or one certain sub-component were not created. So, in many cases, the same text was linked to multiple components and/or sub-components, showing the deeper interconnectivity across them.

In the *first round*, based on a randomly selected sample of the data, both the first and the second authors encoded the data independently. Each coder identified possible educational components and sub-components enabling students' transdisciplinary-oriented learning. The definition of those educational components and sub-components emerging from the data was guided by the educational ecosystem framework introduced by den Brok (2018) and Mueller and Toutain, (2015), which includes educational living- and non- living components. Thereafter, the two coders discussed their elaboration. Both coders saw the need for expanding the guiding educational ecosystem framework in order to also include aspects related to educational processes that were emerging from the data. Consequently, by drawing on the notion of eco-social system (Lemke, 1997, 2006), the coders identified preliminary ACT educational components that play a role in learning, including also process-components, next to living and non-living ones. Those were the *ACT community* engaged in the course (living component); the ACT *pedagogy* and the ACT *structure* (the non-living component), the ACT *process* (the *process-component)*. Additionally, after having discussed individual interpretative differences, the coders have jointly defined preliminary ACT educational sub-components emerging from the data, and also drawing from literature to support the understanding of the data. It should be noted that those interpretative differences were not concerning so much the identification of aspects that constituted possible educational sub-components. Rather, they were related to how to best aggregate and label those multiple aspects within a sub-component.

In the *second round*, based on another randomly selected new sample of the data, the two coders worked independently to encode this new data sample. Both authors were able to encode the new sample according to the preliminary educational components defined in the first round. The pertinence of those preliminary components was thus confirmed. Additionally, the coders refined the definition of the preliminary educational sub-components, also supported by literature. This process led to a more concise labelling of the preliminary sub-components, as well as to a deeper understanding about underlying interconnected learning mechanisms across (sub-)components. Based on those definitions, in the *third round*, all data was then fully encoded by the

second author. Subsequently, the first author examined and confirmed the application of the first coder. This whole process confirmed the pertinence of the already defined educational components, and has contributed to a more nuanced understanding of educational sub-components, their systemic interaction and the underlying learning mechanisms.

Lastly, in the *fourth* round, the second author summarized all the encoded text for each (sub-)component. Those summaries described in a condensed way the mechanisms enabling transdisciplinary-oriented learning (the strengths) including suggestions for further strengthening such learning, and the mechanisms hindering learning (the challenges). Furthermore, by making use of those summaries, the first author distilled learning drivers. Those drivers represent overarching learning mechanisms that keep re-occurring across most of all other educational (sub-) components and that accelerate learning. The drivers activate a wide positive chain of effects, across educational (sub-) components, enhancing learning as well as preventing or tackling learning challenges. Consequently, the second author has examined the application of the first one. The few minor interpretative differences were resolved through discussion.

The next two chapters, reporting Findings 1 and Findings 2, are based on the summaries and final analysis, as a result of the fourth round. Findings 1 discusses ACT educational components, sub-components and mechanisms enabling or hindering students' transdisciplinary-oriented learning. Findings 2 introduces the 7 learning drivers, representing re-occurring mechanisms that accelerate learning.

4.4 Method for validation of the study

Additionally, in order to ensure *validity* and quality of this research, the *audit method* was implemented (Akkerman et al, 2008). The audit method is a validation procedure particularly suited for quality judgement within complex research processes involving interpretations and iterations. The audit procedure concerns a trajectory in which the *auditees* (i.e. the first and second authors running the research process and data analysis) engage an *auditor* (i.e. the fourth author, which is an educational scientist involved as external evaluator) that perform the audit and evaluate the quality of the work done. During a first orientation meeting the two auditees introduced the research scope and research steps to the auditor and made agreements with the auditor on the audit tasks and procedure, based on Akkerman et al, 2008. The two auditees prepared the audit trial report containing i) the description of the research aim and background, research context, conceptual background of the study, research approach, research methods, findings of the study, conclusive remarks, and the positioning of the researchers; ii) all raw data including the focus groups transcripts and the answers to the questionnaire; iii) all processed data including the full coding book, the summaries and the links across (sub-)themes/(sub-)components and mechanisms. Based on the audit trial report, the auditor evaluated the quality of the study.

The outcome of the audit process was positive. 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 conclusive remarks are visibly grounded in the process of data gathering and analysis (visibility), are well substantiated (comprehensibility) and logically and scientifically acceptable (acceptability). Additionally, the auditor provided a few suggestions aimed at strengthening the presentation of the research study in the report. Those suggestions include: to describe in a more detailed way the steps undertaken in data analysis (chapter 4, methods for data analysis); to distinguish more explicitly between mechanisms enabling and mechanisms hindering transdisciplinary-oriented learning (chapter 5); to make the findings more specific in order to increase their relevancy in the practical educational context (chapter 6). Consequently, the first two authors have worked out those suggestions and improved the report accordingly.

5 Findings (1): Educational components

This study reveals that there are four interconnected educational components of the ACT ecosystem that affect students' transdisciplinary-oriented learning for tackling societal challenges. Each component has a number of sub-components.

Figure 2. Educational components and sub-components affecting students' transdisciplinary-oriented learning

Figure 2 graphically maps the distilled four educational components, and related sub-components, that organically interact with each other. Those educational components, and sub-components, are:

- the ACT *pedagogy* (non-living component), representing the approach taken in teaching and facilitating. It includes the following sub-components: *emancipatory pedagogy* and *transmissive pedagogy*;
- the ACT *structure* (non-living component), representing structured elements that constitute the course. It includes the following sub-components: *course design features*, *brokering arrangements, learning materials, learning activities, time and schedule;*
- the ACT *process (*process-component), representing the aspects affecting the learning process at a personal, collaborative, content and output level. It includes the following sub-components: *boundary crossing, quality of relationships, agency and responsiveness, role and identity, academic consultancy and ethical expertise;*
- the ACT *community* (living-component), representing the people engaged in the course. It includes the following sub-components: the *engagement of the community* people and the *staff life-long learning.*

The ACT community is placed centrally in the graphical representation. This is because the students and their learning for tackling societal challenges are central in the ACT course; and also because the views of the students, commissioners and university staff participating to this study are the foundation upon which the other educational components are distilled here.

For ACT staff, it is crucial to take into consideration those educational (sub-)components, and reflect on how to best put them in place in their ACT work. The *Appendix* elaborates on those educational sub-components, and on learning mechanisms taking place within and across (sub-) components. Those insights make clear that the on-going ACT innovation is well enabling students' transdisciplinary-oriented learning through multiple mechanisms (=the ACT strengths). It also makes clear that there are hindering mechanisms that challenge learning, and that need attention (=the ACT challenges).

6 Findings (2): Learning drivers

This study reveals that, within the educational (sub-)components, there are 7 learning mechanisms, which we call *learning drivers*, that accelerate students' transdisciplinary-oriented learning. When they are present, the drivers activate a positive chain of effects enhancing learning across the educational (sub-) components. They also help preventing or tackling learning challenges that may arise in connection to the various (sub-components), so in this sense the drivers have also a mitigating effect or can increase adaptability when challenges emerge. Therefore, the drivers can be seen as crucial conditions for enabling learning throughout the ACT eco-social system. In this chapter, the learning drivers are discussed in terms of how they boost learning, how they are facilitated and of what can block them. Figure 3 summarizes the learning drivers, in connection to the (sub-)component within which they originate.

1. Have transdisciplinary projects matching the teams (*ACT structure – brokering arrangements*)
2. Empower students to be in charge in the midst of challenges (*ACT pedagogy - emancipatory pedagogy)*
3. Transfer course procedures and standards (*ACT pedagogy - transmissive pedagogy*)
4. Build trust and constructive relationships (*ACT process - quality of relationships*)
5. Enable students to navigate & integrate multiple perspective (*ACT process - boundary crossing*)
6. Handle time constraints (*ACT structure - time and schedule*)
7. Embed staff circular learning communities (*ACT communities – staff life-long learning*)

Figure 3. The 7 learning drivers

Learning Driver 1

Have transdisciplinary projects matching the teams

How the driver accelerates learning (*examples*)

Having transdisciplinary projects that well match the students' team disciplinary backgrounds is a fundamental condition for enabling transdisciplinary-oriented learning. Students feel engaged (*agency and responsiveness*) and can cross the boundaries between academia and society (*boundary crossing*) when commissioners are committed; when commissioners welcome the transdisciplinary nature of ACT and are open towards the multiple academic inputs of the students' team (*boundary crossing*); when the project description is aligned to what the commissioner truly needs and it is open enough to enable students to co-develop the direction of the project (*emancipatory pedagogy*) by bringing in their disciplinary expertise (*academic consultancy and ethical expertise*). In this sense it is crucial to couple careful project recruitment with careful team-making composition (*course design features*). When the students are working on a transdisciplinary project that well matches their background, they can learn to make use of their expertise and to be academic consultants (*academic consultancy and ethical expertise*), and thus reach the course learning outcomes (*course design features*). This driver also has a relevant effect in terms of preventing *challenges* that may raise within various (sub-) components. For example, a well-matched link between transdisciplinary project characteristics and students' background can help prevent a drop in students' motivation (*agency and responsiveness)*; prevent problems in the output quality (*academic consultancy and ethical expertise*); and overall can help prevent a misalignment between the course objectives and what students are actually learning (*course design features*).

How to facilitate the driver (examples)

The driver is facilitated by structural means which include: *brokering arrangements* materials such as the communication guidelines upon which the knowledge broker uses to communicate to commissioners about the transdisciplinary character of ACT and the commissioner role

in it; *brokering arrangements activities* such as the communication activities taking place during the brokering process and the final selection of projects matching the ACT transdisciplinary requirements. Possible actions for facilitating the driver more extensively can therefore focus on further refining and strengthening the embedding of those structural means.

What blocks the driver (*examples*)
Important blockages are related, for example, to situations in which there are multiple commissioners working on the same project and having a variety of divergent needs (*boundary crossing*), which makes it unclear to students what the focus of the project is; to situations in which there are too many students from one same study program to accommodate and therefore it is difficult to create well-mixed multidisciplinary teams (*course design features*).

Learning Driver 2

Empower students to be in charge in the midst of challenges

How the driver accelerates learning (*examples*)
When students are empowered to organize themselves, to face challenges collaboratively and to shape their own path in ACT - instead of being spoon-fed with answers -, they learn to take charge of their ACT work (*agency and responsiveness*); they make an extra effort to work in a complex environment in a participatory way (*boundary crossing*) and to build constructive relationships (*quality of relationships*); they feel stimulated to embody the role of academic consultant while being students (*role & identity*). This driver also triggers mechanisms that helps students to overcome some hindering learning aspects related to various educational (sub-)components. For example, the driver enables students to learn to overcome a sense of paralysis and to make choices in spite of uncertainties (*agency and responsiveness*); to overcome the feeling of being overwhelmed due to the complex collaborative character of ACT; to uncover one's own blind spots and learn from one another (*boundary crossing*). Overall, empowering students is crucial for enabling them to navigate challenging situations and to see those challenges not as a deficiency of the course but as an opportunity to learn how to navigate real-life complex environments.

How to facilitate the driver (*examples*)
This driver is especially facilitated through *learning activities*, such as students self-organized activities (e.g. proposal development self-organized workshop), feedback sessions with the coach, reflection meetings with the academic advisor, etc.. Those can be activities suggested by the formal schedule (*time and schedule*) or just developed upon the initiative of the students. Furthermore, the underlying engagement and skills of the ACT staff (*ACT community*) as critical friends are crucial too for boosting the driver and thus for empowering students to make ACT their own.

What blocks the driver (*examples*)
A key aspect hindering the driver is the shortage of time in ACT (*time and schedule*) which can be disempowering for some students. Coaches also find it difficult to empower more dependent students in the short time frame of ACT.

Learning Driver 3

Transfer course procedures and standards

How the driver accelerates learning (*examples*)
Through the transferring of course procedures (e.g. procedures for developing a transdisciplinary proposals, etc.) and of standards (e.g. assessment criteria, etc.), students understand the procedural steps for approaching their proposal development and content work (*academic consultancy and ethical expertise*); feel directed to further take initiative (*agency and responsiveness*); are stimulated to work collaboratively and integrate perspectives (*boundary crossing*); get clarity about the roles of the various people engaged in ACT and their own role as academic consultants (*roles and identity*); etc. Overall, this driver can also help tackle challenges arising within other educational (sub-)components. For

example, it can help students to overcome the feeling of being overwhelmed due to the high complexity of the course by boosting their confidence about how to proceed (*agency and responsiveness*); it can help to reduce the chance that students take shortcuts in their academic consultancy work and thus to strengthen their academic consultancy skills (*academic consultancy and ethical expertise*); etc.

How to facilitate the driver (*examples*)
The transferring of procedural course instructions and standards occurs through *learning materials*, such as the proposal development handbook providing instructive steps and a checklist for writing a proposal; the instructions for confidentiality agreements; the assessment strategy described in the course guide and assessment rubrics; the scientific and ethical code of conduct, etc. Furthermore, the driver is enacted through the directive coaching or advisory activities of ACT staff (*ACT community*), focused on the transferring of instructions and standards (*learning activities*).

What blocks the driver (*examples*)
Lack of knowledge about ACT procedures and standards by the ACT staff (*ACT community)* can block this driver.

Learning Driver 4
Build trust and constructive relationships

How the driver accelerates learning (*examples*)
Cultivating trust and constructive professional relationships helps students to awaken an interest towards one another's viewpoints and towards collaborative and integrative efforts (*boundary crossing*); to jointly handle unexpected challenges (*agency and responsiveness);* to perform effectively as an academic consultancy team (*academic consultancy and ethical expertise*) etc. Cultivating relationships can potentially prevent or help address challenges. For example, it can lay the groundwork for handling constructively different personalities and conflicting perspectives (*boundary-crossing*); it can help prevent difficulties in decision-making (*agency and responsiveness*) and stimulate participatory relationship between students and with ACT commissioners and staff (*emancipatory pedagogy*) and a good working climate. Although it takes time to invest in relationships, it is good to make time for it before working on content (*time and schedule*). This time invested in building relations might in the long run actually help students to handle time constraints effectively.

How to facilitate the driver (*examples*)
A relational attitude and participatory skills of the ACT staff (*ACT community*) can help facilitate team bonding and the building of constructive relationships. *Learning activities* also play an instrumental role in creating a safe environment and boosting relationships. For example: the first meeting between coach and students, the CPD sessions and the self-organized team-building activities appear conducive towards development of professional relational bonds.

What blocks the driver (*examples*)
A main mechanism hindering the driver is the limited time available (*time and schedule*). The (perception of) of having shortage of time makes it difficult to create space for getting to know each other.

Learning Driver 5
Enable students to navigate & integrate multiple perspective

How the driver accelerates learning (*examples*)
Awareness of multiple perspectives, along with communication, enables students to get to know one another and facilitates the creation of a collaborative environment (*quality of relationships*) within the teams, and also with ACT staff. It also helps students to build their own identity within their teams and as a team (*role and identity*). By expanding one's viewpoint and by integrating multiple disciplinary and practical knowledge, students learn to co-define the direction of the project (*agency and responsiveness*), develop an integrative project purpose and research questions and can overall create an academic consultancy

advice of value for society (*academic consultancy and ethical expertise*). Furthermore, being able to handle and integrate multiple perspectives can help prevent a clash in viewpoints and a conflict, which can demotivate students and can block their actions (*agency and responsiveness*). It can also help students to better respond to cultural differences and interpersonal challenges (*quality of relationships*).

How to facilitate the driver (*examples*)
The transdisciplinary (self-)assessment criteria, which are part of the *course design features*, enables the driver by making students aware from the start about the relevance of handling and integrating multiple forms of knowledge throughout ACT. L*earning activities* also help to facilitate the driver. Examples of conducive learning activities include the critical reflections stimulated by the coaches and academic advisors, the Belbin team exercise, feedback activities, etc. *Learning material* also plays a relevant role, for example through the guidance offered in the proposal development handbook for defining an integrative project purpose and integrative research questions.

What blocks the driver (*examples*)
Lack of proper support from ACT staff (*ACT community*) and lack of engagement into multi-perspective and integrative *learning activities* disable the driver and hampers the development of students' capacities to handle and integrate multiple perspectives. The lack of transdisciplinary projects matching the teams (*brokering arrangements*) can put the development of students' cross-boundary capacities at stake too.

Learning Driver 6
Handle time constraints

How the driver accelerates learning (*examples*)
A widely shared perception is that time in ACT is short. Handling constraints related to the (perceived) shortage of time, appears crucial in order to effectively navigate the ACT complex environment and foster students' learning. For example: scheduling from the very start initial meetings face-to-face with advisors and commissioners (*ACT community*) helps in the long run with boundary crossing work (*boundary crossing*) as well as with the effective development of an integrative output (*academic consultancy and ethical expertise);* making time in the first week for cultivating trust and constructive relationships *(quality of relationships)* not only provides a good foundation for working together but it also helps save time in the following weeks and contribute to smooth decision making; transferring course procedures and standards (*transmissive pedagogy*) can also help to save time. Furthermore, learning how to handle time constraints supports students to overcome challenges. For example, it supports students to overcome the feeling of being unable to act due to lack of time (*agency and responsiveness*), of being disempowered (*emancipatory pedagogy*), of being unable to work towards a quality output (*academic consultancy and ethical expertise*), etc.

How to facilitate the driver (*examples*)
The driver can be facilitated through *learning activities* focused on equipping students to navigate time constraints effectively. Another potential way to facilitate the driver is to modify the *course design features* by lightening up certain parts of the course or compacting certain activities without reducing the complexity of the course, or by slightly extending the official time engagement of students, staff and commissioners which in turn can give more breath for handling (the perception of) shortage of time.

What blocks the driver (*examples*)
The driver can be blocked by a heavy and poorly balanced *schedule* across learning activities. It can also be blocked by the perception that the shortage of time disables learning and the capacity to respond to constraints (*agency and responsiveness*).

Learning Driver 7

Embed staff circular learning communities

How the driver accelerates learning (*examples*)

ACT coaches and the overall staff have a fundamental role for boosting students' learning. Students highly value staff support. At the same time, in various cases, students explicitly ask for more support, especially directed towards handling and integrating multiple perspectives (*boundary-crossing*) and responding to challenging situations (*agency and responsiveness*). While some ACT staff people consider themselves experienced, others perceive transdisciplinary learning as a complex field and consider it appropriate to build capacities for supporting at best students' learning. In order to respond to those wishes it is desirable to build ACT staff circular learning communities (*ACT community*), through which circulation of knowledge and capacity building across staff can be stimulated in the long term. This can be implemented next to the already existing preparatory training provided in ACT for new coaches, etc. Well-equipped staff enables students' learning in multiple ways. For example, it enables students to get fully in charge of their work (*emancipatory pedagogy*); to take initiative and to respond to complex challenges (*agency and responsiveness*); to implement suitable procedures (*transmissive pedagogy*); to gain support for their academic consultancy work as well as reflect on ethical concerns (*academic consultancy and ethical expertise*), etc. Additionally, the guidance of the staff can help address learning challenges. For example, it can help to overcome the sense of paralysis students perceive when there are conflicting viewpoints (*boundary crossing*), or the sense of feeling insecure about how to work towards an integrative project output of value (*academic consultancy and ethical expertise*).

How to facilitate the driver (*examples*)

The driver can be facilitated through the implementation of life-long capacity building activities by and for ACT staff. For example, periodical workshops focused on a relevant coaching/teaching/advisory topics led by ACT staff or a guest expert, a circle of sharing discussing key learning challenges faced during the course and how to address them, a buddy system across staff, etc.

What blocks the driver (*examples*)

The busy schedule (*time and schedule*) of ACT staff creates a barrier for engaging staff in capacity building activities and supporting circulation of knowledge.

7 Conclusive remarks

This research study contributed to understanding what affects, and helps to cultivate, students' transdisciplinary-oriented learning in the ACT eco-social system. The study took an action research approach, and it was based on thematic analysis of the views of over 100 people engaged in the ACT course and its on-going innovation.

Firstly, the study identified educational components, and related sub-components affecting ACT transdisciplinary-oriented learning. As revealed through the analysis, those *(sub-) components* systemically interact with each other, and together they create a complex, interconnected and dynamic system. They activate learning mechanisms, and chain of effects, that enables transdisciplinary-oriented learning or actually hinder it. Knowledge about those (sub-) components and their learning mechanisms offers a comprehensive understanding of the strengths and challenges of ACT education, and of its effect on students learning. See chapter 5.

Secondly, within the identified educational (sub-) components the study distilled the following *7 learning drivers:*

1. Have transdisciplinary projects matching the teams
2. Empower students to be in charge in the midst of challenges
3. Transfer course procedures and standards
4. Build trust and constructive relationships
5. Enable students to navigate & integrate multiple perspective
6. Handle time constraints
7. Embed staff circular learning communities

Those drivers represent fundamental conditions for accelerating students' transdisciplinary-oriented learning. The drivers reinforce learning across the educational (sub-) components. They also help preventing or tackling learning challenges that may raise in connection to various educational (sub-components). As such, those drivers can inform the educational innovation practices of ACT staff and can guide future choices for boosting students' transdisciplinary-oriented learning. See chapter 6.

Currently, the findings of this study are being discussed with the ACT community in order to stimulate awareness and facilitate joint reflections and actions in the educational practices, feeding up the action research cycle. Furthermore, the ACT coordination in close collaboration with community people, has already catalysed the integration of some insights emerging from this study with a focus on enhancing the embedding of the learning drivers.

Actions undertaken include:

- the refinement of guidelines for recruiting projects and for communicating with commissioners, which have now a more transdisciplinary focus (learning driver 1);
- the refinement of some of the learning activities to include more cross-boundary aspects for handling and integrating multiple perspectives (learning driver 5);
- the modification of the number of hours formally allocated to coaches for their coaching work which has now increased to cope with their time challenges (learning driver 6);
- the introduction of periodical learning activities and workshops for coaches with the intent to embed ACT staff circular learning communities (learning driver 7).

Appendix: Elaboration Findings (1)

Chapter 5 introduced four interconnected educational components (*Pedagogy, Structure, Process, Community*), and related sub-components, affecting students' transdisciplinary-oriented learning for tackling societal challenges.

This appendix elaborates on those findings, which can in turn inform the educational practices of ACT staff. Here, each identified educational (sub-) component is defined also drawing from literature, and described in terms of its underlying mechanisms enabling transdisciplinary-oriented learning (= the strengths) or actually hindering it (= the challenges). The educational (sub-)components and related learning mechanisms are discussed in systemic interaction with each other, given their explicit interconnectivity.

Educational component: Pedagogy

Pedagogy represents the approach in teaching and facilitating. This ACT non-living component includes two sub-components: *emancipatory pedagogy* and *transmissive pedagogy*.

'***Emancipatory pedagogy***' is about generating *space for reflexivity*, and *free-, self- or group- determined choices*, with the intent to support learning in the direction defined by those involved *(based on findings from this study, and based also on Wals and Jickling, 2002; Jickling and Wals, 2008).*

Enabling Learning Mechanisms (Strengths)

Emancipatory pedagogy was considered highly relevant for enabling students' transdisciplinary-oriented learning, given the large amount of insights shared by participants on this matter. From this pedagogical perspective the ACT staff (*ACT communities*) took more the role of facilitator and critical friend, encouraging students to think and get in charge of their transdisciplinary-oriented ACT work. An emancipatory pedagogy generated *space for reflexivity*. By creating reflexive spaces students learned to give and to take feedback when working with others; to be open towards the other and even uncover their own blind spots (*boundary crossing*); to get to know the different ACT communities they engage with and create participation and bonding across the people involved (*quality of relationships*); to reflect on their role as academics and as consultants and on what this implies (*role & identity*). According to many participants, ACT engaged students in activities that facilitate the creation of such reflexive space, for example in the feedback session with others, in the Belbin test reflections, in the students self-organized presentation activities with other teams, etc. (*learning activities*).

Emancipatory pedagogy stimulated *free-, self- or group- determined choices.* Not spoon-feeding students with answers encouraged them to formulate their own questions and make choices to tackle societal challenges in collaboration with others, and in turn this contributed to the quality of their transdisciplinary content work (*academic consultancy and ethical expertise*). So, students learned to (co-)define in collaboration with others (*boundary crossing*) the direction of the project also based on their expertise (*academic consultancy and ethical reflections*). By not giving clear-cut answers to students when they are challenged by the complexity of ACT, they learned to find their way and make self-determined choices (*agency and responsiveness*). The course activities and materials helped facilitating a process through which students learned to organize themselves and shape their path, e.g. in their self-organized proposal preparation work based on the available handbook (*learning activities and learning material*), etc.

Hindering learning mechanisms (Challenges)

With more space and freedom to choose, students more easily took shortcuts reducing their capability to unfold sound expertise (*academic consultancy and ethical expertise*). Furthermore, for coaches (*ACT community*) it might also be challenging to empower students that are more used to do what they are told, considering also the short time frame of ACT (*time and schedule*).

'***Transmissive pedagogy'*** is about the *transferring of course procedures*, *standards* and *expert-driven knowledge* to students, with the intent to support learning in a specific pre-established direction (*based on findings from this study, and on Wals and Jickling, 2002; Jickling and Wals, 2008*).

Enabling Learning Mechanisms (Strengths)

Transmissive pedagogy was considered partly relevant for enabling students' transdisciplinary-oriented learning in ACT, according to some participants. From this pedagogical perspective, the ACT staff (*ACT community*) took more a directive role by transferring course information. Transmissive pedagogy appears pertinent especially when transferring information about the *procedural* side of the ACT work which is rather complex (e.g. procedures for the assessment). Next to that, in other cases, the transferring of *course standards* (e.g. ethical code of conduct) was considered relevant for learning. Few people experienced that also the transferring of *expert-driven knowledge* supported learning. Such various forms of transmissive pedagogy were seen as relevant, for example, when communicating the ACT (transdisciplinary-oriented) course requirements (*course design*); when conveying expert knowledge or ways to approach things (*learning activities*); when giving instructions for example, through the handbook, about developing a transdisciplinary-oriented proposal (l*earning material*). Overall, it was considered that adopting in appropriate circumstances a transmissive pedagogy provides guidance to students, for example, it gave clarity about people roles and related tasks (*roles and identity*); it helped improving the ACT transdisciplinary-oriented proposal and content work and gaining related skills (*academic consultancy and ethical expertise*); it stimulated awareness about the need for connecting perspectives and for working together (*boundary crossing*); it directed students to take more initiative (*agency and responsiveness*); and it help saving time (*time and scheduling*) etc.. It was suggested more efforts could be done by ACT staff (*ACT community*) to transfer course procedures and standards to students in order for them to feel more secure and assured in the transdisciplinary-oriented ACT context. A transmissive pedagogy was adopted in some materials, e.g. the proposal development handbook providing instructive steps for writing a proposal (*learning material*). It was also enacted through the directive guidance of ACT staff (*ACT community*), for example through coaching activities focused on the transferring of instructions and standards and through advisory meeting in which expert driven knowledge was transferred (*learning activities*).

Educational component: Structure

Structure represents all structured elements that constitute the ACT course. This ACT non-living component includes five sub-components: *course design features, brokering arrangements, learning materials, learning activities, time and schedule.*

'***Course design features'*** is about the overall ACT transdisciplinary-oriented *course design and characteristics,* the *formal tasks assigned to ACT staff* and the *students' assessment* (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

The overall transdisciplinary-oriented ACT *course design and characteristics,* as part of the course design features, was considered a solid basis for learning in a transdisciplinary fashion. It was indicated that ACT distinguishes itself from many other university courses, because of its peculiarity of bringing together students with various disciplinary backgrounds and because of the connectivity with societal challenges and societal actors. The transdisciplinary-oriented design empowered students to not just provide an independent consultancy advice to societal commissioners on real challenges, but to work towards a more integrative work that requires students to closely tune-in and integrate the perspective of commissioners and ACT staff (*ACT community*). This in turn stimulated students' to open up their mind and cross boundaries (*boundary crossing*). Suggestions were also made for exploring the feasibility of having ACT projects (*brokering arrangements*) that involve commissioners (*ACT community)* even more closely into the project in order to foster not only a form of consulting transdisciplinarity, but a more co-creation form of transdisciplinarity.

The ACT design was considered to be overall well-reflected in the materials (*learning materials*), while it was also indicated that a successful learning process depends on the quality of ACT coaches, academic advisors and teachers (*ACT community*). Some cited the need for making the design of the course even more robust, when it comes to make good use of the ACT time (*time and scheduling*) by focusing for example on investing time for team building activities (*learning activities*) given their relevance for enhancing interpersonal relationships (*quality of relationships*) and overall ACT performance.

The *formal tasks of ACT staff* was considered important too. The job of the coach supporting the process work as well as of the job of the academic advisors supporting the academic work were overall highly appreciated. It was suggested that strengthening the collaboration between coach and academic advisors (*ACT communities*) could further support students learning. It was considered relevant to include academic advisors and commissioners from the very start and meet them regularly throughout ACT (*time and schedule*). Suggestions were made to have students make the first appointment with commissioners (*agency and responsiveness*) instead of coaches doing that.

Finally, *assessment* was indicated too, by few participants, as a relevant component in the learning process. Participants expressed their appreciation for the newly developed criteria for assessing students which enable a more comprehensive (self-)assessment for collaborative transdisciplinary purposes (*boundary-crossing*).

Hindering learning mechanisms (Challenges)

While the ACT course design features were overall viewed positively, a few learning challenges were also indicated. A few difficulties included a need for a more clear distinction between the formal tasks and roles of coach, academic advisors and teachers (*ACT community*); a difficult relationship between student(s), coach, advisors (*quality of relationship*) directly affecting the performance of the tasks and the learning process; the lack of engagement of a commissioner and the need for motivated commissioners (*brokering arrangements*). Assessment challenges experienced included the perceived lack of enough nuances in a few assessment criteria and the challenge of grading students on independency in a course that focuses on transdisciplinary collaboration.

'***Brokering arrangements'*** is about the materials used and the activities undertaken throughout the project recruitment phase for connecting academia and society, including *making agreements with commissioners*, developing *transdisciplinary-oriented project descriptions,* and creating a well matched *students' team composition* (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

Brokering arrangements was a crucial underlying component enabling learning at the crossroad between academia and society. Participants indicated the pertinency of having knowledge brokers making agreements with commissioners about ACT work. It was important to explicitly agree with the commissioner from the start about, for example: the transdisciplinary complex nature of the ACT projects which require inputs from multiple disciplines and call for crossing the boundaries between academia-society (boundary crossing); the minimum requirement of time commissioners should make available for students to work collaboratively with them throughout ACT (time and schedule); the rules for confidential projects and the type of confidentiality documents ACT students could sign (academic consultancy and ethical expertise). Having those aspects in place, positively influenced the overall learning experience of the students.

It was considered also relevant to have well-written transdisciplinary-oriented project descriptions, describing general project objectives and project characteristics, upon which students can start their work. It was appreciated that the project descriptions wee well integrating both academic aspects as well as societal aspects (boundary crossing), and were broad enough to provide students space to create their own path and collaboratively define a direction for the project (emancipatory pedagogy). A few people wondered about the possible relevance of

including a section on ethics directly in the project description (academic consultancy and ethical expertise), not just ethics in terms of good codes of conduct but in terms of possible controversial aspects in project societal topics upon which to reflect ethically. It was also appreciated by some when the project description already incorporated some of the aspects needed for drafting the ACT transdisciplinary project proposal as this provided a good starting point for the work of the students (academic consultancy and ethical expertise). This was the case when, for example, the project description included a general problem statement, possible integrative research questions, etc.. Aligning well the project description to the real needs of the commissioner, was also considered important, to avoid creating unreal expectation for students and a drop in students motivation (agency and responsiveness).

The *ACT students' team composition*, had very important effects on the learning experiences of the students. Many indicated that a multidisciplinary and multicultural team composition helped in generating awareness about diverse scientific and cultural perspectives and the value of being able to handle this diversity (*boundary crossing*). When the various expertise of the students composing a certain team could well meet the overall projects' needs, a fruitful learning process was activated and motivation was boosted (*agency and responsiveness*).

Hindering Learning Mechanisms (Challenges)

A challenge faced concerning *brokering arrangements* is that in some cases was difficult to strive for including multiple disciplines in the ACT team project work (*boundary crossing*), even when commissioners wanted that. This is because at time there could be far more students from a single study program to accommodate at the same time and to be put in the same team. Still, however students could make use of their different study specializations in a program, and possible different backgrounds, for bringing in different views and inputs.

Another challenge mentioned was related to handling multiple commissioners for one same project, so it was recommended to make sure there is only one commissioner (and multiple stakeholders if wanted) per project (*course design features*). Few participants pointed out the difficulty to cope with a lack of alignment between what written in the *project description* and what the commissioner needed. A reason for that could also be a change in the vision of the commissioner and the project needs, which might occur after project recruitment and before a project starts. Another challenge indicated was that projects differ from one another, and some were reflecting transdisciplinarity more than others, creating thus differences among teams in terms of their possible transdisciplinary engagement (*boundary crossing).*

Furthermore, a couple of students expressed difficulties in terms of their team composition, as they were working on projects that only marginally were matching their expertise, which contradicts the ACT course design (*course design features*). One student indicated also challenges in a team due to the lack of balance in teams composition in terms of having only one student with a certain expertise and few students with another same expertise hampering a good cross boundary process (*boundary crossing*).

'***Learning materials'*** is about the *materials* provided to support learning (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

Various *learning materials* and resources are provided in ACT. There has been quite a positive response, with many citing appreciations, for the Proposal Development handbook. Overall, the creation of a handbook for developing a transdisciplinary-oriented proposal was considered a positive development by many. According to some, the handbook put the proposal development more into the hands of the students (compared to the previous teacher-led workshop format) providing them with the freedom to make their own decisions (*emancipatory pedagogy*). Students were able to set their own pace of learning (*agency and responsiveness*) with the material provided, and were encouraged to learn with and from the other (*boundary crossing*). It was suggested to provide even more accuracy in the instructions provided in the handbook (*transmissive pedagogy*) and for better balancing depth of instructions with conciseness. The log frame part was considered relevant by many,

but overall there were questions on how to best bring it forward to the students. It was suggested to make more use of supportive knowledge clips, to adopt a more strong methodological step-wise approach for writing a proposal, and further encourage students' reflection on ethical societal dilemmas, and not just code of conduct (*academic consultancy and ethical expertise)*.

The Communication and Personal Development (CPD) reader was considered clear. Especially useful was the new handout to prepare the first meeting with commissioner. Suggestions were given for including more multiple perspective-taking exercises in CPD material (*learning activities*), to better align CPD with the transdisciplinary character of ACT. It was also suggested to frame the Belbin test in a more behavioural way instead of ways of being. Concerning *other ACT material* relevant for both students and staff (study guide, slides, guidelines guidelines), some expressed the wish to have a guide for team processes (with process related tips, hints, questions, etc.), while others were doubting whether such a guide should be incorporated in the course (*course design features*). While, overall learning material in ACT was appreciated it was also indicated that more guidance could be given concerning multi-perspective communication and academic consultancy transdisciplinary aspects (*boundary crossing*).

Hindering Learning Mechanisms (Challenges)

For some, the Proposal Development Handbook was so structured that students might lose connection with their motivation (*agency and responsiveness*), and the instructions of the log frame was too detailed. Overall, studying well the ACT learning material was also hampered by the limited time available in ACT (*time and schedule*).

'Learning activities' is about the *activities* supporting learning (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

Various learning activities take place in ACT. There has been quite a positive response about the relevancy of the proposal development *activities* for enabling students' transdisciplinary learning. Many expressed appreciation for having the initial proposal development workshop, as it gives a direction to the project (*transmissive pedagogy*) while it also opens up the space (*emancipatory pedagogy*) to reflect on and to organize the meeting with the commissioner. Some suggested to include a brainstorm session (*time and scheduling)* before the proposal development workshop, to give even more opportunity to students to get to know their team mates (*quality of relationships)* as well as to learn with and from the others (*boundary crossing*). Others requested for more videos (*learning materials*) to be included in the proposal development handbook to support proposal development learning activities. In one case a participant expressed a preference for the old format made up of teacher-led proposal development workshops.

Concerning the Communication and Personal Development (CPD) *activities*, participants found relevant, for example, the awareness raising exercise concerning the role of the consultant (*roles and identity*); the team building exercises which encourage students to get to know each other (*quality of relationships*); the Belbin's test giving insights into how a team functions as a consultancy team (*role and identity*). Some participants suggested to strengthen transdisciplinary collaborative learning (*boundary crossing)* throughout CPD activities, and to give enough room for learning about the use of feedback.

There were also *other learning activities* considered relevant. Those were, for example, the students self-organized activities; the various meetings between coaches and students encouraging reflexivity and motivation (*emancipatory pedagogy*), and also feedback and multi-perspective awareness (*boundary crossing*); joint proposal development

sessions with other teams and related coaches; the meetings with the academic advisors in an early stage supporting learning from multiple perspectives (*boundary crossing*); the meetings with the ACT coordinator to share experiences (*emancipatory pedagogy*), etc. There were also suggestions about, for example, having even more activities for group bonding (*quality of relationships*); considering having teams that share proposal with each other to stimulate learning (*academic consultancy training*); having coaches that engage students more in looking at things from multiple perspectives (*boundary crossing*), etc.

Hindering Learning Mechanisms (Challenges)

According to a couple of participants, there were challenges experienced in connection to the Belbin test. The test "pre-assigns" students to a certain role, and students feel discouraged when they are missing a Belbin "role" in their team (*roles and identity*). Properly framing the Belbin test activity during the CPD classes and through the coach work is crucial. Next to that, when the ACT work is not properly framed as transdisciplinary collaborative learning, for example throughout CPD classes and the activities with the ACT staff (*ACT community*), the learning can be hindered.

'***Time and schedule'*** is about aspects related to *time allocation* and *scheduling* (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

ACT *scheduling* offered possibilities to students to be self-organized and create their own agenda (*emancipatory pedagogy*), for example through the way the proposal development handbook guided students to plan their activities (*learning material*). Some students made suggestions to include in the *schedule* some time to get to know their team members more in depth (*quality of relationships*) before starting with content work. Other suggestions, concerning *time allocation*, included anticipating some meetings, for example having students to hold a first meeting with the commissioners earlier, to speed up proposal development. There were also some suggestions to switch the order of some learning activities, and have CPD activities always before the proposal development activities, to enable students to get to know the team first (*quality of relationships*) before engaging into content work.

Hindering Learning Mechanisms (Challenges)

A widely shared perception was that the course is intensive and *time* is short for enabling in-depth learning. The short time frame of the course posed challenges. For example, lack of time was experienced as disempowering by some *(emancipatory pedagogy),* and according to others it also put at stake the quality of the students' work (*academic consultancy and ethical expertise*). According to some, the *scheduling* for proposal development gave little time for integrating inputs of staff and commissioners (*ACT community*). On the other hand, the CPD workshops *(learning activities)* sessions were experienced by some as too long. Having CPD activities (*learning activities*) half way in the course, in a time when students felt that time was needed to give attention to content, was challenging. With little time available, coaches (*ACT community*) struggled too in their coaching work, for example in terms of fostering in-depth reflexivity (*emancipatory pedagogy*).

Educational component: Process

Process represents the aspects affecting the learning process at a personal, collaborative, content and output level. This ACT process-component includes five sub-components: *boundary crossing, quality of relationships, agency and responsiveness, role and identity, academic consultancy and ethical expertise.*

'***Boundary crossing'*** is about the process of *being aware of diversity* in relation to one another's backgrounds, disciplines and views (identification); *communicating* about viewpoints, knowledge and practices (coordination); *expanding one's viewpoints* by including viewpoints and knowledge of others (reflection); *handling and integrating* viewpoints, knowledge and practices (transformation) (*based on findings from this study, and on Akkerman & Bakker, 2011).*

Enabling Learning Mechanisms (Strengths)

Boundary crossing processes were considered crucial for learning. Many comments were made concerning the relevance of *being aware of diversity* in relation to one another's' backgrounds, disciplines and views. Some participants cited that throughout ACT they gained awareness about differences in approaches depending on the disciplinary backgrounds, and differences in views depending also on the cultural backgrounds (national, professional and personal). This in turn provided the ground for getting to know each other (*quality of relationships*); enabled students to gain clarity about their expertise and what they can and what they cannot offer to their commissioners (*academic consultancy and ethical expertise);* provided clarity also about the profile of a team, about the commissioner, etc. *(role and identity)* and overall created the basis for transdisciplinary work. The reflections stimulated by the coaches and academic advisors (*ACT communities*) and other activities, e.g. the Belbin test, (*learning activities*) have supported this awareness process.

Many acknowledged the importance of *communicating* about viewpoints, knowledge and practices. Communication in ACT enabled students to get to know each other (*quality of relationships*) and create a collaborative environment; to share different knowledge and perspectives for co-defining the direction of the project (*emancipatory pedagogy*); to give and receive feedback that can in turn improve their academic consultancy performance (*academic consultancy and ethical expertise*); etc. Communication appeared relevant across students in a team in order to learn from each other beyond what you can learn from a teacher (*emancipatory pedagogy*), as well as across students-commissioners-coaches-advisors, etc. (*ACT community*).

Some participants highlighted they were able to *expand one's viewpoints* by including viewpoints and knowledge of others. Some students indicated that, by tackling their complex project query, they learned to be open minded, to expand own view by considering multiple perspectives and to put themselves into the shoes of their societal commissioner and others (*academic consultancy and ethical expertise*). The Belbin test, switching roles within the students' team, and other activities (*learning activities*) contributed to this process of supporting expansion of one's viewpoint which is appreciated.

Finally, many participants considered very relevant the process of *handling and integrating* viewpoints, knowledge and practices. A variety of comments were made on this matter. The different perspectives that emerge in the ACT project work, call also for capabilities to be flexible towards others' viewpoints, knowledge and practical needs, and to handle differences and possible clashes in perspectives. Some expressed a sense of satisfaction in terms of managing well to integrate multiple views in order to address the complex ACT transdisciplinary project challenge (*brokering arrangements*), to bring focus to the project and to create something of value (*academic consultancy and ethical expertise*). Brainstorm activities, communication and feedback (*learning activities*) and constructive relationships (*quality of relationships*) created a good ground for a processes of integration. There was appreciation for the new set-up of the proposal development phase *(learning activities and learning material),* that enables turning the different perspectives of the

students, commissioner and ACT staff (*ACT community*) into joint research questions that embody all the different perspectives. There is overall good awareness that handling and working towards integration is needed in the real world as professionals (*academic consultancy and ethical expertise*), and that this process can be further strengthened by receiving more guidance in some cases by ACT coaches and staff (*ACT community*).

Hindering Learning Mechanisms (Challenges)

Some students mentioned that they faced difficulties in *communicating* with the commissioner about the scope of the project because the commissioner did not know what he/she wanted (*brokering arrangements);* another student also said that transdisciplinarity was hard to implement due to the lack of availability of the commissioner (*brokering arrangements*) which hampered communication. Some other teams faced communication challenges throughout various moments in the ACT activities (*learning activities)* due to the contrasting viewpoints of commissioners, academic advisors as well as coach *(ACT community*), and in some cases also due to the different academic language used (and different meaning given to words) related to the different disciplinary backgrounds of the students (*course design features*). Another challenge mentioned was that students were hesitant to ask for feedback as they are being assessed for independency (*course design features*).

In some cases students found it not easy to *expand own viewpoints,* to stretch from a certain disciplinary perspective to another one, and to shift the focus between content and process as implied in ACT (*course design features*). While differences enhanced curiosity, they sometimes also left students paralysed, also in cases in which a clash in viewpoints was experienced. Coach support (*ACT communities*) on this matter was needed, according to a couple of participants.

Also, the process of *handling and integrating viewpoints, knowledge and practices* was not always smooth. For example, in some cases it was hard for non-technical people to handle and integrate technical aspects (and the other way around) as the differences among those aspects is rather big; it was also hard to bring together academic conceptual aspects and consultancy practical ones (*course design features*); and there was a sense of frustration experienced by a few people when not being able to work towards integration. Again, receiving proper support by ACT coaches and staff (*ACT community*) was considered crucial to navigate challenges.

'***Quality of relationships'*** is about the *value of building relationships* and related relational experiences (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

The *value of building relationships* and acknowledging interdependencies in the ACT context was widely recognized by participants. Many people emphasized the fundamental role that constructive relationships play in the ACT work. People cited the relevance of creating time (*time and scheduling*) for facilitating group bonding, for cultivating trust and constructive relationships across students and with staff and commissioners. According to participants, this helped awakening an interest for in-depth learning with and from each other (*boundary crossing*); it allowed students to work in the long run faster (*time and schedule*) and effectively as a consultancy team (*academic consultancy and ethical expertise*); it helped handling challenges (*agency and responsiveness*) and dealing with differences and different personalities (*boundary crossing*). Some students mentioned experiences with their coaches facilitating team bonding process that were perceived as very useful (*emancipatory pedagogy*), and experiences in the first CPD workshop session (*learning activity*) that helped creating a safe environment.

Hindering Learning Mechanisms (Challenges)

Someone cited challenges within the team because of the lack of opportunity (*time and schedule*) to get to know one another, again confirming the relevance of investing in building relationships; while another mentioned challenges between coach and students due to

different cultures (*boundary crossing*) and lack of investment in relationships affectively learning negatively.

'***Agency and responsiveness'*** is about the process of *defining and initiating a course of action*, of *responding to a challenge*, and the underlying *motivation and the belief* one can take actions (*based on findings from this study and also on Tassone et al., 2017)*

Enabling Learning Mechanisms (Strengths)

Several comments were made by participants with regard to the relevancy of engaging ACT *students in defining and initiating a course of action*. Overall, it was considered that the course set up (*course design features*) positively confronted students with the need to take charge of their own project in between academia and society. It was perceived that empowerment is also stimulated, for example, by the ACT staff (*ACT communities*) encouraging students to take initiative, take risks and learn from own mistakes (*emancipatory pedagogy*); by the proposal development handbook and other material (*learning material*) encouraging students to organise themselves and take action accordingly. As a result, ACT students learned to be pro-active as academic consultants (*academic consultancy and ethical skills*). By means of various activities (*learning activities*) students managed to, for example, prepare well in advance before relevant meetings with other parties (*time and schedule*); engage into literature review and get acknowledged on a topic before asking questions; contact experts from and outside the university in order to receive content inputs (*boundary crossing*); set the direction of their work while being open to the viewpoint of other parties (*boundary crossing*), etc.

Participants also appreciated that ACT engages students in learning processes aiming at *responding to a situation or a challenge*. It was appreciated that the ACT design (*course design features*), engaged students to address real complex challenges in society by providing an advice on how to tackle that challenge (*academic consultancy and ethical skills*). Students learned to find their way for responding to difficult situations (*emancipatory pedagogy*) which inevitably arise given the real-life character of ACT, for example a change in vision of the commissioner, the unforeseen illness of relevant people, etc. This in turn supported students to be flexible, to handle frustration in a constructive way, and to be willing to step out of a comfort zone (*academic consultancy and ethical expertise*).

The *underlying motivation and belief that one can take actions*, also played a role in learning, according to some participants. Students felt motivated and confident when the project matched their expertise (*brokering arrangements*). Several students felt activated by the facilitation work of the ACT staff (*ACT community*) which enabled them to reflect on their motivation, their action-oriented beliefs, and define the direction of their learning based on their learning needs (*emancipatory pedagogy*).

Hindering Learning Mechanisms (Challenges)

*A*lso due to the short time frame of ACT (*time and scheduling*), it was challenging for some staff people (*ACT community*) to well activate students towards *initiating actions* when students by default put themselves in a condition of dependency towards a coach, an academic advisor, etc.; and it was also hard to develop collective forms of agency in those cases when one or few students in a team tended to lead the actions or when there were miscommunication challenges (*boundary crossing*). Also, some students felt unprepared when it comes to *responding to a situation or a challenge,* for example when it came to navigating stressful factors and overcoming feelings of being paralyzed and overwhelmed by the ACT complex environment (*ACT course design*). The guidance of ACT staff (*ACT community*) was considered crucial to handle those feelings. Furthermore, not every student had the same *motivation,* leading to different engagement of students within a team. For few students it was also difficult to believe in themselves and gain an identity as an academic consultant, beyond being a student going to class (*role and identity*). In other cases, students perceived a lack of confidence when there was a mis-match between the project focus and their expertise (*brokering arrangements*). They felt demotivated when feedback of ACT staff (*ACT community*) were

perceived as too negative, when their perspective was not integrated (*boundary crossing*), or when they perceived their project output was not well appreciated and being used by the commissioner (*ACT community*).

'***Role and identity'*** is about the process of *awareness*, the *experiences and dilemmas concerning the role or identity* of an individual or a group when holding a certain position within a certain context (*based on findings from this study, and on Burke and Stets, 2009*).

Enabling Learning Mechanisms (Strengths)

Gaining *awareness* of one's and others' identity and role, was considered a relevant process in ACT. Some students indicated that throughout the course by being in a team (*course design features*) and through course activities, e.g. the Belbin test (*learning activities*), they became aware of the diverse character of fellow students and differences existing across people (*boundary crossing*); of their role as academic consultant versus being an academic as well as of the variety of positions one can take in an academic consultancy team as team member, as manager, etc. (*academic consultancy and ethical skills).* It was also suggested by ACT staff to enhance awareness about the differences between the role of the coach and the one of the academic advisor (*ACT community*) to support better the learning process of the students.

Some participants highlighted too the relevancy of engaging into *experiences and dilemmas*, which helped exploring roles and identities. Some cited that by positioning oneself within the project one can develop professional attitudes as a real-life academic consultant (*academic consultancy and ethical skills*). Others mentioned that by engaging into concrete experiences (*emancipatory pedagogy*) they felt activated to act (*agency and responsiveness*) and to develop an identity as real professionals in between academia-society.

Hindering Learning Mechanisms (Challenges)

In some cases it was difficult to gain an identity as an academic consultant because some students stayed compliant (agency and responsiveness), and tended to see themselves as students and not as professionals. On this matter few students felt a dilemma between having to act as an academic consultant, while being students doing a course and being graded on their performance (course design features). Another also mentioned that with the Belbin's test, there is a challenge that students get pre-defined identities (transmissive pedagogy) and it might be difficult for students to deviate from those pre-set identities.

'***Academic consultancy and ethical expertise'*** is about the process of unfolding *capabilities to work in an academic consultancy manner*, to *make ethical considerations* and to *deliver quality work* (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

There is a wide array of comments being made about the value of ACT in engaging students in *unfolding capabilities to work in an academic consultancy* fashion. Aspects mentioned as particularly enabling the development of academic consultancy capabilities, included for example, having an initial broad research objective and questions of the commissioner (*brokering arrangements*) which can be then fine-tuned taking into account team expertise; scheduling from the start (*time and schedule*) face-to-face discussions (*learning activities*) with the academic advisors *(ACT community*) to look critically at the proposal and support ethical considerations; the possibility to act as academic consultant (*role and identity*) and bring real value to society through the final advice given.

Important capabilities learned throughout ACT that were mentioned, included: thinking critically and looking for the question beyond the question; being flexible and adapting to different ways of thinking;

thinking in a systemic and integrative way; handling challenges and complexities; being ethical. On this last point, participants indicated the relevance of engaging in making *ethical considerations* and in reflecting on the project topic from an ethical perspective (*learning activities).* Given the transdisciplinary-oriented nature of ACT, it was valued that ethical considerations include not only codes of conduct, but also considerations about the project itself and its possible impact on society. There was a positive response by some with regard to the efforts made in terms of *quality of work* concerning proposal development and the presentation of content information by students. There was no comment provided by participants with regard to the quality of work of the final product, as this was finalized and submitted after receiving inputs from the participants.

Hindering Learning Mechanisms (Challenges)

It was mentioned that in some cases students failed to read or critically evaluate documentation (*learning material*), in other cases students felt insecure about what how to proceed (*transmissive pedagogy*) and found it difficult to crystallize the project problem from multiple perspective (*boundary crossing*), all of which challenged the process of building academic consultancy expertise. In some cases further support from ACT staff (*ACT community*) could be instrumental for addressing those challenges. Another learning challenge faced was due to the different interpretations (*boundary crossing*) of the research questions by the engaged ACT staff and commissioner (*ACT communities*) that students found difficult to handle when developing their academic consultancy work. Also, it was considered that the little time available in ACT (*time and schedule*) could hamper the possibility to deliver quality work, could stimulate students to take shortcuts and in a couple of cases the proposal quality was in fact considered not high.

Educational component: Community

The Communities represents the people participating to the course. This living-component of the ACT ecosystem includes two subcomponents: the *engagement of the community* people and the *staff life-long learning.*

"***Engagement of the community people***" is about the engagement of various ACT people participating and contributing to the course (*based on findings from this study*).

The analysis made explicit that it is through the participation of the various students, staff (teachers, coaches, academic advisors and knowledge brokers) and societal commissioners, within their different roles, that the ACT course can be enacted. Students engagement and their transdisciplinary-oriented learning for tackling collaboratively societal challenges, supported through the engagement of staff and societal commissioners, were indicated to be a core aspect of the course. Exploring educational components and sub-components enabling students' transdisciplinary-oriented learning, constituted also a central focus of this study. It was based on the views of the engaged ACT people and their experiences in the course, that those relevant educational components (and sub-components) were defined in this study. Therefore, *enabling and hindering learning mechanisms* connected to the engagement of those communities were already elaborated in this report when discussing in the above sections of this chapter all other educational (sub-)components (pedagogy, structure and process).

The *"**staff life-long learning**"* is about the *continuous capacity building and learning of the ACT staff* in order to best facilitate students' learning (*based on findings from this study*).

Enabling Learning Mechanisms (Strengths)

It was perceived that students learning also depends on the staff capacity to facilitate it. The continuous capacity building and learning of the ACT staff was therefore considered crucial. The ACT staff participating to this study, brought up the relevance of wanting to learn and to keep learning in order to facilitate at best students' learning. The innovation of ACT focusing on cultivating students' transdisciplinary-oriented learning was appealing to coaches and other staff. Many changes introduced in the course (e.g. the new and revised learning material and activities) were considered useful by the staff. However facilitating transdisciplinary learning required expertise that, for some, were partly new and need to be developed. Many suggested they wanted to get more tools and gain more insights on how to best support students, through *pedagogy*, *structure* and *process,* to face ACT transdisciplinary challenges, to expand viewpoints and integrate disciplines. Staff people suggested the relevance of participating to learning sessions and workshops, to implement a buddy system, to share and to learn with and from one other and to deepen the sense of being a community. This would enable the more experienced people to share their expertise fostering circularity of knowledge, would support capacity building, reflexivity and experimentation, and overall it would help cultivating learning in ACT.

Hindering Learning Mechanisms (Challenges)

The limited time available was perceived as a barrier for keeping learning as staff.

Positionality of the authors

Valentina Tassone is assistant professor at Wageningen University in the field of responsible educational innovation, and is coordinator of the ACT course. In collaboration with the other co-authors and in discussion with the ACT communities, Valentina defined the research objective and approach, conceptual background and research methods. She conducted some of the focus groups. Additionally, she supported Cassandra Tho throughout her analysis of the data, by being a second coder and by providing a contextualized understanding of the data given her knowledge about ACT. She is the main writer of this report.

Cassandra Tho is researcher at Wageningen University in the field of cross-boundary learning, and is external to ACT. She was never involved in the ACT course. In this study, she participated to some of the focus groups to take notes and she transcribed all the data from the focus groups and questionnaires. Cassandra was the first coder throughout the data analysis process. She was responsible for creating summaries of the encoded text, reporting the voices of the ACT communities. The findings of the study presented in this report, entirely draw from her summaries.

Stefan Wahlen is professor at the University of Giessen in Germany, in the field of sociology and sociology of consumption. In the past, Stefan was ACT coordinator. He supported the initial development of the study and the definition of the research aim, needs and context. Stefan collected a part of the data through focus groups. Furthermore, he was responsible for setting up the Qualtrics questionnaire.

Perry den Brok is professor at Wageningen University in the field of educational sciences, and chair of the 4TU Centre for Engineering Education. Perry was never involved in the ACT course. He contributed to this study by evaluating the validity of the whole research study as independent evaluator, according to the audit method. This included also the examination of all raw and elaborated data. Based on this evaluation, Perry confirmed the quality and validity of this study. Additionally, he provided feedback aiming at strengthening the presentation of the research study in the report, and contributed to its finalization.

This combination of authors positionalities has been fruitful. The first and third authors, holding an in-depth understanding about the ACT course, brought-in the necessary knowledge about ACT. On the other hand, the second and fourth authors with no involvement and no direct knowledge on the ACT course, brought-in a more distant perspective, guaranteeing objectivity and quality of the study and of the elaborated results.

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