Research Article

Valentin Fiala*, Bernhard Freyer, Milena Klimek, Alexandre Fahringer

How do you teach transdisciplinary competences for food and farming systems research? Insights from the course “System Analysis and Scenario Technique”

<https://doi.org/10.1515/opag-2018-0059>

received June 24, 2018; accepted October 13, 2018

Abstract: In this paper we evaluate whether the course “System Analysis and Scenario Technique” at BOKU University can equip students with the necessary competencies to perform transdisciplinary research to foster the integration of science, technology, policy and practice. Furthermore, we investigate what the most effective didactic methods applied in the course are, and whether the course qualifies as transdisciplinary pedagogy. The course follows the simplified framework of a transdisciplinary case study and tries to transfer such an approach into the traditional curricula of Master programs. An online survey among former participants of the course was conducted. Results for the years 2015/16 and 2016/17 indicate that the course indeed has potential to increase transdisciplinary competencies among participants and could therefore qualify as transdisciplinary pedagogy. Students expressed that work with real-world cases and stakeholders from outside the university was the most effective didactic method. However, the study also showed that there were limits in integrating real-world cases within the course. Students complained about the high workload and time constraints. Short-term solutions might include optimizing case selection and student guidance. Long-term solutions beg for a reorganization of traditional Austrian curricula that would allow for the appropriate arrangement of the course with other classes. These results highlight some of the advantages, but also drawbacks of moving transdisciplinary education outside of standard curricula.

Keywords: transdisciplinary learning; transdisciplinary pedagogy, transdisciplinary case studies, system analysis; scenario development, higher education

1 Introduction

“Agricultural sciences nevertheless have to operate at the interface between technological, economic, natural and social systems; and between different knowledge systems and policy arenas. They also have to provide credible science in a context of competing narratives, and interpretations, of how to achieve sustainable agriculture.” (13th European IFSA Symposium, 2018, http://www.ifs2018.gr/en/themes/symposium_themes).

As a response, the 18th IFSA Symposium called for the integration of science, technology, policy and practice and asked what competencies key actors in these fields need to enhance a dialogue between them (13th European IFSA Symposium 2018). The integration of scientists and non-scientists to solve complex real-world problems can be called transdisciplinary research (see Hadorn et al. 2008). A transdisciplinary dialogue between key actors indeed seems to be fundamental for solving such complex, real-world problems, and ultimately for sustainable development (Krainer and Winiwarte 2016; Lang et al. 2012). To understand food and farming systems, transdisciplinary approaches are essential as research in this field should be participatory (Darnhofer et al. 2012) and include stakeholders throughout the entire research process (see the development of farming systems research in Bingen and Gibbon (2012). Although transdisciplinary research has experienced a rise in popularity since its emergence in the late 1970s, it still faces a large number of cultural, institutional, organizational and psychological challenges (Lang et al. 2012). One necessary and often overlooked solution in overcoming such challenges is education and training of students in higher education.

*Corresponding author: Valentin Fiala, University of Natural Resources and Life Science, Vienna (BOKU), Austria, E-mail: valentin.fiala@boku.ac.at

Bernhard Freyer, Milena Klimek, Alexandre Fahringer, University of Natural Resources and Life Science, Vienna (BOKU), Austria

As key stakeholders are educated at universities¹, higher education institutions in general have been facing increasing demand to partake in beneficial societal transformation processes through transdisciplinary research (Krainer and Winiwarter 2016); in doing so they have the obligation to teach those skills to their students. Therefore, it is even more surprising that until recently, transdisciplinarity played such a small role in higher education.

“The relevance of transdisciplinary research within sustainability science (in addition to interdisciplinary research) is almost mainstream nowadays. In contrast to this, transdisciplinarity receives rather limited consideration within academic teaching and learning concepts.” (Merck and Beermann 2015, p. 19)

Although transdisciplinarity continues to play only a minor role in mainstream curricula, there has recently been a stronger call for teaching that encompasses experimental learning and real-world problems, including in the area of food and farming research (Francis et al. 2015; Lieblein et al. 2007), and many novel teaching initiatives are emerging. However, as many educational programs and curricula have not been designed for flexibility, many of these new initiatives try to find their home outside of the often more rigid structure of normal curricula of Bachelor and Master programs. Courses that explicitly focus on training students’ transdisciplinary competencies through theory and practice often take place in form of summer schools, larger research projects or other extra curricula activities (Grant et al. 2018).

Consequently, in this paper we take a closer look at the course “Systems Analysis and Scenario Techniques”², which tries to bring a simplified transdisciplinary case study into the standard curricula for students studying organic farming systems and agro-ecology. To our knowledge it is the first paper which evaluates the effectiveness of bringing transdisciplinary case studies into a rigid course format. We hypothesize that using a case study approach in a standard course structure will have positive learning effects on the students. However, we also foresee limitations due to constraints caused by classical course formats and inflexible programs. The objective of

this work is to cast light on the potential advantages and drawbacks of integrating transdisciplinarity into a normal course structure instead of extra-curricular initiatives. In doing so, we hope to further the discourse about the education of key actors in food and farming systems.

Our analysis was guided by the following questions:

- Does the course increase student competencies in transdisciplinary research?
- What are the most effective didactic methods to achieve transdisciplinary competencies?
- Does the course qualify as transdisciplinary pedagogy?

This paper is of exploratory character. We conducted an online survey among former participants of the course. In this, we asked them to assess the transdisciplinary competencies they gained in the course, let them evaluate which didactic methods used in the course were the most effective, whether the course qualifies as part of transdisciplinary pedagogy, and to comment on the general importance, strengths and weaknesses of the course.

2 Transdisciplinarity: What and How to Learn?

In the following section, we develop a theoretical framework to answer our research questions, including three parts: (i) competencies necessary for transdisciplinary research, (ii) didactic methods for training, and (iii) broader pedagogies for learning transdisciplinary research.

The term transdisciplinarity was first coined in the 1970s (Hadorn et al., 2008) and has since increased in popularity. Transdisciplinary research crosses disciplinary borders as well as the borders of research institutions. The concept is more than a theoretical approach, a specific method or a discipline on its own. Although it does not aim to abolish the principle of disciplinarity, it does seek out a new mode of knowledge production. Transdisciplinarity widens the benefits of academic research from its traditional perspectives to societal, political and economic perspectives from multiple disciplines and stakeholders, expanding upon interdisciplinarity with its integration of stakeholders (Jahn 2008). Consequently, transdisciplinarity is seen as an organizational principle that reduces the limitations of problem solving capacities of single disciplines (Mittelstraß 2005). Although it is difficult to find a commonly accepted or shared definition (Jahn, 2008), at its core, transdisciplinarity has four main concerns:

¹ Many key actors in agrofood systems have had some form of higher education. In 2016 roughly 1,500 students completed a study program at the University of Natural Resources and Life Science in Vienna (BOKU) (Glöckl, 2017). Many of them will take diverse positions in our current agrofood system in which they are confronted with complex situations and problems.

² The authors of the paper were involved in designing this lecture. Bernhard Freyer taught the course together with Rebecca Paxton until the 2014/15 school year when Valentin Fiala took over.

“First the focus on life-world problems; second the transcending and integrating of disciplinary paradigms; third participatory research; and fourth the search for unity of knowledge beyond disciplines.” (Hadorn et al. 2008, p. 29)

Accordingly, transdisciplinarity is not something easily achieved, and researchers often find themselves in novel and unfamiliar territory. With the high level of complexity transdisciplinarity often tackles within research problems, it becomes clear that an ideal transdisciplinary research process differs vastly from classic disciplinary work (see Lang et al., 2012) and requires a specific set of competencies.

2.1 Transdisciplinary competencies

What are the necessary competencies people have to have to successfully conduct transdisciplinary research? Nash et al. (2003) lists several competencies that should be achieved in transdisciplinary training programs and distinguishes them into three categories: attitudes, knowledge and skills (see also Grant (2013), who draws similar conclusions for food and farming research). The distinction between these categories is merely an analytical one, as the skills necessary to perform transdisciplinary practices involve—among others—combinations of emotional attitudes and cognitive skills (see Reckwitz 2002; Schatzki et al. 2001). Yet they are useful to obtain an overview of the personal requirements of transdisciplinary research.

2.1.1 Attitudes

According to Nash et al. (2003, p. 45), training courses should encourage participants to take over the following attitudes to successfully conduct transdisciplinary research:

“(i) to value transdisciplinary education, (ii) to be open to, accepting of, and respecting contributions of other disciplines, (iii) be curious about what other disciplines offer, (iv) be willing to risk venturing outside own area of expertise, (v) to be optimistic that risks taken can lead to advances, (vi) to be aware of own limits and abilities.”

2.1.2 Knowledge

Within the second category of transdisciplinary competencies, Nash et al. (2003) name a certain set of knowledge that should be achieved in training courses. An

understanding of: transdisciplinary research; the history of interdisciplinary science and philosophy of science; the core theories and research methods used in biological, behavioral, and population sciences; and research ethics.

These categories are very broad and quite vague. Furthermore, they were derived from research in the field of tobacco science. For the area of farming systems research, we believe there is need for a more specific set of knowledge (which to our knowledge has not been defined so far); we suggest two main types:

First, specific knowledge from different disciplines connected to food and farming topics is essential to obtaining a holistic picture of the agro-food system. Although this knowledge is important, it is not part of our empirical research in this paper. As such knowledge is obtained through other courses within the Master program, it is seen as a sort of pre-requisite of our students, and therefore the course does not aim to equip students with this knowledge.

The second type is grounded knowledge about systemic thinking and practice. Systems thinking and practice is a necessary foundation and framework to understand and apply inter-, and transdisciplinarity (Fiala and Freyer 2016; Freyer et al. 2010; Hadorn et al. 2008; Ison 2008).

Systems thinking is driven by the assumptions that interconnections matter and that many properties of a whole cannot be explained when only considering their isolated parts (Von Bertalanffy 1968). Of the many existing definitions of ‘system’, a prominent one is that of Ison (2008, p. 147):

“An integrated whole whose essential properties arise from the relationships between its parts”.

Systems thinking is a key competency for transdisciplinary research, because it helps to reflect the holistic perspective of stakeholders’ complex real-world problems. It also enables the combination of different disciplines, perspectives and knowledge types to analyze it, therefore ensuring inter-, and transdisciplinarity. Since its introduction, system theory has witnessed strong diversification³ (Ison 2008), but in all their diversity, different system approaches share more or less similar core concepts: (i) the idea of emergent properties; (ii) boundaries; (iii) hierarchies; (iv) structure (elements and their relations); (v) function; and (vi) feedback (Checkland and Scholes 2007; Ropohl 1999).

³ A common distinction in literature is that in hard (ontological), soft (epistemological) and critical systems approaches all of them can deliver different foundations for transdisciplinary research (Badwen 1995; Fiala and Freyer 2016)

Therefore, we add that students taught in transdisciplinary research should understand the core concepts of systems thinking and practice, and be familiar with its core concepts.

2.1.3 Skills and abilities

Finally, Nash et al. (2003, p. 45) names the following skills as necessary to conduct transdisciplinary research: (i) communication and interpersonal skills; (ii) critical-thinking skills; (iii) perseverance in overcoming obstacles; (iv) patience in knowing that the benefits of training take time to be realized; (v) inclusive thinking; (vi) broad-gauged, contextually oriented theorizing; (vii) application of strong research methods; and (viii) use of a methodologically pluralistic approach.

Having already stated that skills are more complex than attitudes or knowledge, this becomes even more obvious when we look at four capabilities which are defined by Muhar, Visser, and Van Breda (2013, p. 123) and should be considered in transdisciplinary research practice and teaching:

Integration capability: Being appreciative of the potential value of different disciplinary and non-disciplinary contributions and being able to integrate them.

Innovative methodological capability: Having the ability to tackle the complementarity of methodologies, such as quantitative, qualitative and transformative approaches and to find the right balance between them.

Communicative capability: Being able to generate and negotiate new concepts and representations capable of forging shared understanding across disciplinary divides and transcending the schism between science and society.

Mutual learning capability: being able to learn with society in different contexts how to develop shared problem framing of both real-world and research problems, including research questions and strategies.”

Expertise in both skill sets described by the authors above should be an outcome of a course on transdisciplinary research. In the next section, we focus on how to train students to develop and use these competencies.

2.2 Teaching transdisciplinary competencies: didactic methods & pedagogies

There are various ways to teach transdisciplinary competencies to students, but all of them have to use certain didactic methods and follow to some degree fitting pedagogies. Nash et al. (2003) lists the following didactic

methods that are suitable for training transdisciplinary competencies: course work, seminars and workshops, interactive groups, institutional environment, mentoring relationship and research experience. We will later see how the course under evaluation used these methods.

Transdisciplinary pedagogical approaches or pedagogies are situated on a higher level and combine different didactic methods to ensure transdisciplinary learning. In general, McGregor (2017) states that transdisciplinary learning (i.e. the training of abilities that helps people from different areas to deal with complex problems in a collaborative way) needs an inquiry based pedagogical approach. More specifically, he names nine possible higher education pedagogies that should ensure transdisciplinary learning of students (see table 1).

As we pointed out in the introduction, there exist many attempts in the area of higher education of food and farming systems to adopt such pedagogies and apply fitting didactic methods outside of normal Bachelor and Master curricula. Prominent examples are transdisciplinary case studies realized via summer schools⁴ or larger research and education projects. Such case studies are powerful devices to teach and train people in transdisciplinary research, often following the approach of an embedded case study introduced by Scholz and Tietje (2002)⁵: Researchers, students and stakeholders work together over a longer period of time to investigate and improve real-world situations. For example, in the case study “Leben 2014”,⁶ two universities paired up, several courses were matched with each other to contribute to the project, and over a period of two semesters, students worked together with several stakeholders from nine rural Austrian communities to create future scenarios for the region Oberpinzgau. Other attempts are one to two week-long summer schools, which focus on experiential learning about food and farming systems.⁷ Those summer schools “provide an exceptional format for learning about food systems. As residential, immersion programs, they offer opportunities to use learning methods and pedagogical approaches that maybe infeasible in traditional courses.” (Grant et al. 2018, p. 169).

The course under evaluation incorporates characteristics of transdisciplinary case studies and

⁴ see e.g. ELLS case Study competition: <https://www.euroleague-study.org/en/112101>

⁵ See for examples the transdisciplinary case studies as described in (Freyer and Muhar 2006; Steiner and Posch 2006)

⁶ The project Leben 2014 acted as a model for the lecture under evaluation (see Freyer and Muhar (2006).

⁷ See e.g. the activities of the World Food System Center at ETH Zürich (Grant 2013).

Table 1: Transdisciplinary pedagogies

Pedagogy	Description
integrative curriculum	teaches students to make connections between different topics and issues
transformative learning	helps students to shift mental and emotional perspectives on topics and issues
inquiry based learning	helps to see broader patterns and underlying dynamic through iterative questioning
authentic curriculum	education is purposeful and meaningful, because it is centered around issues that are topical and relevant for students
value analysis	helps to be aware of other people's values when analysing their viewpoints
learning communities	creates interdisciplinary groups of people that learn together
deep education	context specific, participatory, holistic, interactive education, that applies deep principles to gain deep understanding leading to deep actions
paradigm shifts	perspective consciousness leads to paradigm awareness
double loop learning	helps to question everyone's governing principles, values and norms

Source (McGregor, 2017, p. 14)

experimental learning and seeks to transport these elements into normal curricula. We assume that this attempt will face some challenges, but also show potentials and maybe some advantages in comparison to extra-curricular activities. In the following section, we describe the course in detail.

3 “System Analysis and Scenario Technique” – a simplified transdisciplinary case study

The course is a 5 European Credit System (ECTS) seminar for Master students from the area of agro-ecology and organic farming systems, held once every winter semester. *“The aim of the course is to create communities of practice, which help students to use systems thinking conceptually and in practice. It seeks to challenge reductionism and disciplinary / institutional isolation, and to create new knowledge for real-world situations.”*⁸

It therefore has a clear systems-based transdisciplinary orientation, and participants are encouraged to deal with real-world problems.

The main approach to achieve this aim is that of a simplified version of a transdisciplinary case study, and regardless of the obvious limitations of a weekly course, the course “System Analysis and Scenario Techniques” attempts to transfer some of these core transdisciplinary methodological characteristics into the framework of a

Master course within a traditional curriculum. The class begins by splitting into groups of four to five students. Each group has to conduct a systemic analysis of one real-world case (chosen from organizations involved in the wider Viennese organic agrofood system (e.g. farmers, retailers, alternative food networks etc.). They work together with their “case owners” (i.e. important stakeholders of their case-organization). On the foundations of this analysis, the groups create future scenarios for their cases that illustrate how the case owners could overcome current problems (as defined by the case owners and the students).

The main difference to a traditional case study is that not all students work on different aspects of the same case, but each group of students focus on a smaller case study. This concession was made due to organizational and institutional reasons, as it proved difficult to find fitting larger case studies and the smaller group reports fit more into the traditional structure of courses.

Teaching transdisciplinary case studies involves two major responsibilities (see Steiner & Posch, 2006): providing information on how to conduct transdisciplinary research, and the supervision of students during their case study work.

As such, the teacher first introduces students to system and scenario development. As part of this introduction we offer several training sessions on creating system diagrams during class time. During the introduction, students individually also read specific scientific articles that explain and further illustrate core methodological concepts of system and scenario development (see Chermack and Lynham 2002; Ison 2008; Meadows 1999). They then write a short essay about their reading discussing the objectives, main messages of the article and how it could be useful for their group work.

⁸ See the course description in Boku online: <https://online.boku.ac.at/BOKUonline/wbLv.wbShowLVDetail?pStpSpNr=281163&pSpracheNr=1>.

Table 2: Didactic methods of the course

Activities	Explanation
Input on system development	Input on system theories, methods for data collection and interpretation, introduction to system diagrams
Input on scenario development	Introduction to theoretical background of scenario development, explanation of methodological approach
Course work on systems diagrams	Training in creation of several systems diagrams in class (system map, influence diagram, multiple cause diagram (Ison, 2008))
Reading	Reading of three scientific articles (Chermack & Lynham, 2002; Ison, 2008; Meadows, 1999), for different classes of the course
Essays about reading	Three short essays, corresponding to each reading, discussing the objective, main messages and the usefulness for the course work of each text. The essays are brought to class and discussed in a plenary session
Seminar work 1: Application of methodology	This activity refers to the seminar work. Specifically, to the application of the methodology the students were introduced to during the course
Seminar work 2: Interaction with case owners	This activity refers to the seminar work. Specifically, to the interaction with the case owners (problem definition, data collection, feedback on models and scenarios etc.)
Seminar work 3: Class presentations, discussions and feedback	This activity refers to the seminar work. Specifically, to the presentation of the ongoing and final group work to the class (discussions and feedback)

Supervision of students during their case study work, is organised as follows. Students are pre-organized into fitting case study groups and put into contact with their respective case owners. They are required to organize meetings, communication and gather data for their system and scenario development. They must summarize their findings in a written group report, which they present at the end of the semester. The groups have various chances to present their work during the semester and receive feedback from the lecturer and their fellow peers. Table 2 summarizes and explains the main didactic methods within the course. We can see that most of the didactic methods named by Nash *et al.* (2003) are found within the course (with one exception: institutional environment). See table 2.

4 Material and Methods

In the winter semester 2013/14, the course “System Analysis and Scenario Technique” was reorganized and the structure described above was established. In the four years from 2013/14 until 2016/17, 146 students participated in the course (on average 36.5 per year). The list of the participating students was retrieved via the online teaching system BOKU online. One hundred and eleven of the students’ university email addresses could be recovered⁹ and those students were invited to fill out an

online survey concerning the class. The survey was active from December 5th-19th 2017 and was anonymous.

Forty-five students participated in the survey and 31 filled it out completely. However, the participation varied highly between the different years. For the year 2015/16, 14 students and for 2016/17, 16 students responded. For those two years, the rate of response was acceptably high to use for this investigation (43 % for 2016/17 and 37% for 2015/16¹⁰). The response rate for the other two years was much lower: 5% for 2013/14 and 11% for 2014/15. Therefore, only the results for the years 2015/16 and 2016/17 were used.

A questionnaire was created for the survey using the theoretical framework described above. The questionnaire began with a question to assess student memory of the course and describe its aims. Other parts of the questionnaire were separated into two major parts. In the first part, questions about the influence of the course on the transdisciplinary competencies of the participants (i.e. attitudes, knowledge and skills) were asked (research question 1). The second part focused on the didactic methods applied in the course, its qualification as transdisciplinary pedagogy as well as its general importance and strengths and weaknesses (research question 2 and 3). A pre-test among former students was conducted to check if the questionnaire was understandable.

⁹ For 2013/14, 19; for 2014/15, 10; for 2015/16, 6 email addresses were missing.

¹⁰ The 37% refers to all students that participated in the seminar this year. If the responses of the number of students we actually invited were examined, the return rate would be 44%.

For the majority of questions, a unipolar, five-part rating scale was used (see table 3-5). Here, participants indicated to what degree they agreed with certain statements.¹¹ Since the data are based on an interval scale, the location parameter medians, and the 1st and 3rd quartile as well as the distribution of answers were calculated (see Bortz & Döring, 1995).

For those questions that asked about transdisciplinary attitudes, the attitudes listed by Nash et al. (2003), were used to create the questions. The rating of questions concerning student skills were built on the foundation of the capabilities of Muhar et al. (2013), rating of questions about transdisciplinary pedagogies were created using the respective pedagogies from McGregor (2017).

Open-ended questions were also included in the survey, allowing participants to formulate answers. These included defining the terms system and core systems concepts. Answers were evaluated using the core concepts of systems theory mentioned below (Checkland and Scholes 2007; Ropohl 1999). The different concepts each participant could name were documented. Furthermore, students were asked to describe course strengths, weaknesses and ways of improving. The answers about the strengths, weaknesses and improvements were paraphrased and in a second step grouped into categories.

Finally, there were two special questions in the survey. In one question, participants were not asked to rate but to rank the different didactic methods according to their influence on acquiring competencies. Since the data were placed on an interval scale, once again the location parameters median, and the 1st and 3rd quartile as well as the distribution of answers were calculated. For the second question, we applied a semantic differential ((Osgood 1952) see Figure 1). Semantic differentials were used to capture connotative meanings of terms or object. For this, a number of bipolar contrasting pairs of adjectives were formulated. Participants had to assess on a bipolar rating scale which end of the pair fitted the object of interest better (see Bortz and Döring 1995). In our survey, the object of interest was the skillset of the participants. We used the list of transdisciplinary skills of Nash et al. (2003) to create seven contrasting pairs. One pole of the pair was a transdisciplinary skill, the other was a fitting opposite. Participants had to indicate on a bipolar five-part rating scale which adjective fitted their skillset better. To present

the semantic differential, the means of the answers were calculated. These two specific survey techniques were not only important for our data collection but were also used to capture the attention of the participants to enable more complete surveys.

All the questions mentioned above were analyzed using only descriptive statistics. There was no comparison between students from different years.

Ethical approval: The conducted research is not related to either human or animal use.

5 Results

In the following section, we present the results of the survey for the years 2015/16 and 2016/17. As the differences between them appear to be quite small, we do not distinguish the results between the two years.¹²

5.1 Recollection of the course

From the total of 34 students of the two course years participating in the survey, 26 remember the aim of the course and 25 described it in their own words. None of the participants were able to recall the aim of the course word for word, but all participants could identify its core activities or concepts. This indicates that students have some memory of the course, which might increase the quality of their responses.

5.2 Transdisciplinary competencies

Table 3 shows the distribution of answers and the location parameters for questions about transdisciplinary competencies (attitudes, knowledge and skills).

5.3 Attitudes

The vast majority of participants stated that they followed the attitudes necessary for transdisciplinary research as mentioned by Nash et al. (2003). Most participants agreed with the attitude: “I value transdisciplinary collaboration”

¹¹ There were two exceptions where a unipolar, five-part rating scale was used, but participants did not have to “agree” with statements; for question K1, participants assessed their knowledge; with I1, they indicated the importance of the seminar for their future work (see table 3 and 5).

¹² For the 27 relevant answers, the median—as the most important location parameter for most of the questions—differed only 11 times (and never more than one rank). The questions with differences were (see table 3-5): A1.5 (0,5 ranks difference), A2.1 (0,5), A2.3 (1), A2.4 (1), A2.5 (1), K2 (1), SK4 (1), TP1.5 (0,5), TP1.6 (1), TP 2.1 (1), TP2.2 (1)

Table 3: Transdisciplinary competencies

Attitudes									
Attitudes (A1) Please assess to what degree you agree with the following statements	strongly agree	agree	partly agree	disagree	strongly disagree	no answer	Median	1. quartile	3. quartile
(A1.1) I value transdisc. collaboration	80%	17%	3%	0%	0%	0	strongly agree	str. agree	str. agree
(A1.2) I am open to combine disciplines	69%	24%	3%	3%	0%	1	strongly agree	partly agree/ agree	str. agree
(A1.3) I venture outside my expertise	52%	31%	10%	7%	0%	1	strongly agree	agree	str. agree
(A1.4) I am willing to take risks	34%	34%	28%	3%	0%	1	agree	agree	str. agree
(A1.5) I know my abilities	22%	33%	41%	0%	4%	3	agree	agree	str. agree
Influence of the course on attitudes (A2): seminar encouraged me to take over this attitude	strongly agree	agree	partly agree	disagree	strongly disagree	no answer	Median	1. quartile	3. quartile
(A2.1) I value transdisc. collaboration	50%	25%	18%	7%	0%	0	str. agree/ agree	partly agree	str. agree
(A2.2.) I am open to combine disciplines	39%	39%	18%	4%	0%	1	agree	partly agree	str. agree
(A2.3) I venture outside my expertise	31%	24%	41%	3%	0%	1	agree	partly agree	agree
(A2.4) I am willing to take risks	19%	22%	37%	15%	7%	1	partly agree	partly agree	agree
(A2.5) I know my abilities	5%	10%	55%	20%	10%	3	partly agree	disagree	partly agree
Knowledge									
Knowledge: Please assess to what degree you agree with the following statements	very high	high	medium	low	very low	no answer	Median	1. quartile	3. quartile
(K1) I assess my knowledge about system thinking and practice	0%	19%	58%	19%	4%	3%	medium	part. Agree/ disagree	partly agree
(K2) The seminar increased my knowledge of system thinking and practice	strongly agree	agree	partly agree	disagree	strongly agree	no answer	Median	1. quartile	3. quartile
	46%	25%	21%	7%	0%	2%	agree	partly agree	str. agree
Skills and abilities									
Skills and abilities: assess if you agree that the seminar improved the following skills of yours	strongly agree	agree	partly agree	disagree	strongly disagree	no answer	Median	1. quartile	3. quartile
(SK1) integrate inputs from different scientific disciplines	25%	46%	13%	17%	0%	6	agree	partly agree	str. agree/ agree
(SK2) integrate inputs from non-scientific actors	28%	40%	28%	0%	4%	5	agree	partly agree	str. agree
(SK3) balance complementary methodologies	12%	32%	44%	12%	0%	5	partly agree	partly agree	agree
(SK4) communicate across disciplinary divides	8%	46%	33%	8%	4%	6	agree	partly agree	agree
(SK5) create a shared understanding	17%	50%	25%	8%	0%	6	agree	partly agree	agree
(SK6) foster mutual learning	29%	46%	25%	0%	0%	6	agree	Partly agree/ agree	str. agree

in which 80% of the survey participants “strongly agreed”. This was followed by the attitudes “openness to combine different disciplines” and “venturing outside my own expertise”. “Willingness to take risks” and “knowledge about own abilities” received the least degree of agreement.

When asked whether the course encouraged them to take on these attitudes, most participants also agreed, but not so strongly as with the attitudes themselves. The median for: “I value transdisciplinary collaboration” was situated between “strongly agree” and “agree”. For: “openness to combine different disciplines” and “venturing outside my own expertise” the median was “agree”. For the last two attitudes “willingness to take risks” and “knowledge about own abilities” the median was “partly agree”. We see here that the perceived influence of the course correlates with the overall agreement for an attitude.

The results indicate that participants believed that they have the necessary set of attitudes to perform transdisciplinary research and that to some extent, the course encouraged them to take on such attitudes.

5.4 Knowledge

Fifty-eight percent of the survey participants assessed their knowledge about systems thinking and practice as “medium”, 19% as “high” and 19% as “low”. None of the participants assessed their knowledge as “very high”, but one person (4%) perceived it as “very low”. In comparison to transdisciplinary attitudes, student knowledge of the associated theory seems to be less pronounced.

When asked to give a definition of the term *system*, 83 % were able to provide a definition. When asked about *core systems concepts*, 66% were able to offer an answer. The actual core systems concepts were not mentioned very often. The most frequently named were feedback (9 times), followed by boundaries (7), elements (6), relations (6), hierarchies (5), emergent properties (5) structure (2) and functions (1). This would indicate that systems knowledge is not very high. However, it seemed that many students did not fully understand the questions, because other terms used in the course, such as hard or soft systems, scenario development or SWOT analysis were often mentioned. Finally, students were asked whether the course improved their knowledge of systems thinking and practice. Here, most students strongly agreed (46%) and only 7 % disagreed.

To summarize, students were of the opinion that the course increased their knowledge about systems thinking and practice (which is a core foundation of

transdisciplinary research), but they also saw themselves as far from being experts in this field (which is also understandable, because the course is often a student’s first interaction with systems thinking and practice labeled as such).

5.5 Skills

To assess how the course influenced the skills of the students, we asked two different sets of questions. First, we used the transdisciplinary skill set from Nash et al. (2003) to create a semantic differential with seven contrasting pairs of adjectives to describe the skill sets of participants. One pole of each pair always represented a transdisciplinary skill, the other the opposite.¹³ Survey participants indicated along the spectrum between each pair what adjective describes their skill set better. Figure 1 shows how participants assessed their skill set. After that, participants were asked whether participation in the course pushed them to one or the other side of the pairs (see also Figure 1). On average, the students viewed themselves slightly more on the side of the transdisciplinary skill set, but not necessarily to a high degree. The only exception to this trend was the skill pair “eager to take action” and “patient and binding”. Here, students positioned themselves slightly on the side of “eager to take action”. The way student skill sets were influenced through the course correlates very clearly with the general assessment of the sets. According to the differential, the course had the most impact on the critical thinking of students, followed by adaptation, holistic thinking and overcoming obstacles.

In addition to the semantic differential, students were also asked to assess how participation in the course fostered the transdisciplinary skills mentioned by Muhar et al. (2013). The four broad capabilities were divided into six questions to avoid asking two questions at once.

The results indicate that for most of the skills, students agreed that the course had a positive influence on them. For five of the six questions, the median of the answers was “agree”. The least agreement could be found with the skill “ability to balance different methods”. Here, the median was only “partly agree”. The rating of the influence indicates that students think that the course improved their skill sets. However, the semantic differential provides a slightly more differentiated picture if the course was able to equip students with the necessary skills.

¹³ Not every skill mentioned by Nash et al. (2013) was used. We were not able to create a sufficient pair for the skill “application of strong research methods”. Therefore, it was excluded.

Figure 1: Semantic differential on transdisciplinary skills

5.6 Methods and Pedagogies in “System Analysis and Scenario Technique”

5.6.1 Didactic Methods

Different didactic methods were used in the course (Table 2). Students were asked to rank them according to influence on their attitudes, knowledge and skills, from most to least influential.

The results clearly show that the work on real-world cases had the largest influence on their learning process. All three activities associated with the practical group work were those most frequently placed in the top three rankings (see medians in Table 4). The practical work with real case owners on concrete real-world problems seems to have been the most influential part of the course. This was followed by the teachers’ input on systems development and in-class group work on system diagrams. On the lower end of this ranking are the activities connected with reading tasks (reading three scientific papers and writing short essays about them).

5.6.2 Transdisciplinary pedagogies

When asked whether, in their opinion, the course could qualify as part of certain transdisciplinary pedagogies (McGregor 2017), the students “mostly agreed”. Table 5 shows

that the median for all answers to questions addressing whether the course could be part of a useful transdisciplinary pedagogy was “agree”. Most students found that the course enabled them to recognize broader connections, shift to holistic perspectives and see broader patterns.

The majority of students also highly agreed that the course formed part of a holistic and integrative education, as well as an education that was useful and relevant for the students themselves.

5.6.3 Strength, weaknesses and general importance

When asked about the importance of the course, 32% of survey participants considered the course as “very important” for their future work. Thirty-two percent regarded the course as “important” and 24% as “somewhat important”. The median for this answer was “important”. Thus, in general the course seems to play a weighty role in the education and perceived future relevance of the students. When asked about strengths, weaknesses, and possible improvements to the course, 24 students named strengths, 22 offered weaknesses and 11 suggested ways in how to improve the seminar.

The most strengths named fell into the categories of: work on real-world cases (14 times), followed by a motivating and enthusiastic teaching style (7 times); unique in comparison to other courses in the Master

program (6); work in interdisciplinary learning groups (6); systems methodology (4); general quality of the course (4); appropriate work load (2); scenario methodology (2); plurality of activities (1); interesting case studies (1); and its practicality (1).

These strengths confirm the results of the ranking of the didactic methods and show that working with real-world cases was very important for this course.

Common weaknesses were found in the areas of: problems regarding group work (group forming, size, etc.) (4 times); high workload (3); confusion about tasks (3); quality of case studies (3); complex and abstract subject matter (3); confusion about grading (3); unclear structure of the course (2); repetitions within the presentations (1); weak learning materials (1); and little connection to current research and innovation agendas (1).

Suggestions for improving the course could be divided into the following groups: reduction of workload and stress (4); provision of more time in the curricula for this course (4); more guidance from course (3); clearer presentations from teacher (3); reduction of group size (2); and to shift focus from theory to practice (2). Six suggestions only mentioned once are not listed here.

6 Discussion – bringing transdisciplinary approaches into standard curricula

Before focusing on the importance of our results for education in food and farming research, we want to point out two method- and framework-related remarks.

First, the main method for creating results was a quantitative questionnaire. How far this method is appropriate for identifying student competencies and their opinions about the quality of a course, must be regarded with some caution. While an online survey may be an appropriate tool for assessing the attitudes of participants, it only provides incomplete information about their de facto knowledge and skills. More detailed qualitative research, such as interviews with individuals or focus groups with multiple students, could provide deeper insights. In addition, ongoing long term evaluations (see Grant 2013) would help to understand different transdisciplinary teaching approaches. Finally, we wish to point out that the small sample size of this work makes generalizations difficult. Our research is explorative and should spark discussion and further investigations.

Second, the theoretical framework applied here to describe transdisciplinary competencies shows that there is a clear need for a discussion about what those competencies in the field of farming systems research might be. Competencies, such as those introduced by Nash et al. (2003), have not been created for this particular field of research, and specific knowledge concerning systemic thinking and practice as an important foundation for transdisciplinary research is not mentioned. A discourse should be started within the IFSA community about what explicit food and farming transdisciplinary competencies are.

This paper focused on the challenges and benefits of using a transdisciplinary case study approach in a traditional course format within a standard Master program. Through a survey among former participants we specifically focused on the questions: Can the course

Table 4: Didactic methods and importance of the course for further work

Didactic methods	Please rank the following activities of the seminar in regard to their importance on your attitudes, knowledge and skills											
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8	Rank 9	Median	1. quart.	3. quart.
(DM 1) Seminar work 2: Case owners	41%	14%	23%	0%	5%	5%	5%	5%	5%	2	4,5	8
(DM 2) Seminar work 3: Class presentations, discussions and feedback	19%	14%	24%	10%	10%	0%	10%	10%	5%	3	6	9
(DM 3) Seminar work 1: Methodology	14%	27%	9%	23%	14%	9%	5%	0%	0%	3,5	3,5	5
(DM 4) Input on system development	5%	14%	5%	36%	23%	0%	14%	5%	0%	4	4	6,5
(DM 5) Class work on system diagrams	14%	14%	19%	5%	5%	19%	14%	10%	0%	4	2	6,5
(DM 6) Input on scenario development	5%	5%	9%	9%	18%	27%	5%	14%	9%	6	2	4,5
(DM 7) Readings	5%	10%	5%	5%	10%	10%	19%	19%	19%	7	1	3
(DM 8) Essays on readings	0%	0%	10%	0%	10%	14%	5%	29%	33%	8	2	6

Table 5. Transdisciplinary pedagogies and importance of the course for further work

Transdisciplinary pedagogies									
The course can help students to (TP1): <i>strongly agree</i> <i>assess to what degree you agree with the following statements about the seminar</i>	strongly agree	agree	partly agree	disagree	strongly disagree	no answer	Median	1. quartile	3. quartile
(TP1.1) see connections between different topics	36%	64%	0%	0%	0%	5	agree	agree	str. agree
(TP1.2) shift mental and emotional perspectives	21%	54%	21%	4%	0%	6	agree	part. ag/ ag.	agree
(TP1.3) see broader pattern	29%	54%	17%	0%	0%	6	agree	agree	str. agree
(TP1.4) be aware of other people's values	32%	40%	28%	0%	0%	5	agree	partly agree	str. agree
(TP1.5) create an interdisciplinary group	36%	36%	20%	4%	4%	5	agree	partly agree	str. agree
(TP1.6) question everyone's governing principles	16%	36%	36%	4%	8%	5	agree	partly agree	agree
The course qualifies as part of: (TP2)	strongly agree	agree	partly agree	disagree	Str. disagree	no answer	Median	1. quartile	3. quartile
(TP2.1) a holistic and integrative education	52%	32%	16%	0%	0%	5	str. agree	agree	str. agree
(TP2.2) an education, which is relevant for the students	46%	38%	17%	0%	0%	6	agree	agree	str. agree
Importance of the course									
Importance: <i>assess to what degree you agree with the following statements about the seminar</i>	very important	important	somewhat important	a little bit important	Not at all	no answer	Median	1. quartile	3. quartile
(I1) importance of the seminar for further work	32%	32%	24%	12%	0%	5%	important	partly agree	agree

help to equip Master students with transdisciplinary competencies? Does the course qualify as transdisciplinary pedagogy? And what are the most effective didactic methods to achieve both?

Our results indicate that the course has the potential to increase some of the necessary competencies for applying transdisciplinary research. Students that participated in the course found that most of the changes in their path towards transdisciplinary research occurred in their personal attitudes. Participation in the course also increased their knowledge of systems thinking (as a necessary requirement for doing transdisciplinary research), but still, on average, participants assessed their knowledge as only mediocre. Also, in regard to their skillsets most students agreed that the course had positive effects, with some notable exceptions (e.g. not increasing patience of students).

The results concerning applied didactic methods, and therefore our second research question, clearly show that according to the participants, activities connected with

work on real-world cases (interaction with case owners outside university, practical application of methodology and feedback in class) had the most influence on their competencies. This is consistent with research connecting education and curriculum development to encompass participatory methods, real-world problems and experiential learning among other action-oriented educational approaches (see e.g. Francis et al. 2015; Lieblein et al. 2007). This further substantiates the potential of transdisciplinary case studies to assist in the acquisition of necessary competencies. Moreover, when directly asked whether the course qualified as part of different transdisciplinary pedagogies, most of the students agreed.

Thus, it seems bringing transdisciplinary and experiential learning into normal curricula has clear benefits. However, our research also clearly showed limitations of such attempts, and explains why many such activities take place outside normal curricula. Time constraints within traditional university programs and

workload restrictions (see also the listed weaknesses of the course) make it difficult to harvest the full potential of transdisciplinary case studies and experimental learning. As one of the survey participants stated:

“The seminar is in my opinion ideal for two semesters. In this way it would be possible to really handle the cases in a good way.”

These results are verified when we look at the general evaluation of the BOKU courses.¹⁴ The BOKU evaluation also confirmed one of the main weaknesses found in our survey, that the most negative aspect of the course for both years was the amount of time required from the students. In 2016/17 and 2015/17, 30% and 85%, respectively, of the responders said the workload was too high.

Thus, although more complex and interdisciplinary research fields are being created or are gaining popularity—e.g. agroecology, sustainability studies, food studies, systems, etc. (Méndez et al. 2015)—examples of experiential action-based learning, including transdisciplinary courses that focus on real-world problems and stakeholder integration, continue to be difficult to find (Parr et al. 2007). However, integrating transdisciplinary case studies and experiential learning into the standard structure of Master curricula have benefits that are often overlooked:

- Grant et al. (2018) list several quality design criteria for experiential food systems learning, and state that summer schools face time constraints which hinder them from: raising awareness about the wider context, exploring food and farming systems in detail, applying interdisciplinary approaches and integrating knowledge produced by diverse stakeholders. All of these are important criteria for ensuring experiential learning. A semester long, weekly course helps to overcome such problems by regular training, reflections and time for additional research by the students
- If a course is part of the standard curricula, it will be available for more students and will therefore reach a higher number of key stakeholders
- The integration of experiential and case study-based learning into standard Master curricula also offers the opportunity to align and match the courses with the rest of the program. This can help with appropriate chronology of courses, to capitalize on synergies, and lead to a truly integrative curriculum for the students

Ultimately, it seems that larger one or two semester long transdisciplinary case studies could combine many of the strengths of summer schools and standard curricula. However, such projects are hard to realize without additional funding (see the example of Leben 2014 (Freyer and Muhar 2006)). Consequently, there is a need for a new way of teaching, which brings transdisciplinary case studies into the curricula of higher education and which can work around institutional or program level barriers. Luckily, with the increased popularity of alternative models of research and education among research agendas and among funders of research projects, there is increasing interest in creating novel teaching methods within higher education (Mitrany and Stokols 2005). This research is one contribution to such a discussion.

Conflict of interest: Authors declare no conflict of interest.

References

- Bawden R., On the systems dimension in FSR, *J. Farm. Syst. Res. Ext.*, 1995, 5, 1-18
- Bingen J., Gibbon D., Early Farming Systems Research and Extension experiences in Afrika and possible relevance for FSR in Europe, In: Darnhofer I., Gibbon D., Dedieu B. (Eds.), *Farming Systems Research into the 21st Century: The New Dynamic*, Springer, Dordrecht, Heidelberg, New York, London, 2012
- Bortz J., Döring N., *Forschungsmethoden und evaluation*, Vol. 3, Springer, Berlin, 1995
- Checkland P., Scholes J., *Soft Systems Methodology in Action: Including a 30 Year Retrospective*, Wiley & Sons, Chichester, 2007
- Chermack T.J., Lynham S.A., Definitions and Outcome Variables of Scenario Planning, *Hum. Resour. Dev. Rev.*, 2002, 1, 366-383
- Darnhofer I., Gibbon D., Dedieu B., Farming systems research: an approach to inquiry, In: Darnhofer I., Gibbon D., Dedieu B. (Eds.), *Farming Systems Research into the 21st Century: The New Dynamic*, Springer, Dordrecht, Heidelberg, New York, London, 2012
- Fiala V., Freyer B., *Systemtheoretische Grundlagen*, In: Freyer B. (Ed.), *Ökologischer Landbau*, Hauptverlag, Bern, 2016
- Francis C., Ostergaard E., Nicolaysen A.M., Lieblein G., Breland T.A., Morse S., Learning Agroecology through Involvement and Reflection, In: Méndez V.E., Bacon C.M., Cohen R., Gliessman S.R. (Eds.), *Agroecology: A transdisciplinary, participatory and action-oriented approach*, CRC Press, Boca Ranton, 2015
- Freyer B., Bingen J., Helgenberger S., How Transdisciplinarity becomes a Member in the Club of Science - Some Preliminary Thoughts on the Contribution of Systems Theory to Theorizing Transdisciplinarity, In: Trappel R. (Ed.), *Cybernetics and Systems*, Austrian Society for Cybernetic Studies, Vienna, 2010
- Freyer B., Muhar A., *Transdisziplinäre Kooperation in der universitären Ausbildung: die Fallstudie “Leben 2014” in der Nationalparkregion Hohe Tauern, Oberpinzgau; ein Projekt im*

¹⁴ The evaluation is not mandatory, and the rate of response is typically very low. For the seminar in 2015/2016, only 7 students evaluated the lecture (18%) and in 2016/17, 10 students (26.3 %) responded.

- Rahmen des Programms Kulturlandschaftsforschung, Facultas Verlag, Wien, 2006
- Glösel J., Mayer H., Wissensbilanz 2016. Retrieved from Wien, 2017
- Grant M., Youth Encounter on Sustainability: A Transdisciplinary, Multicultural, and Immersive Education Program, In: Kaufmann J., Mo L.K. (Eds.), *Handbook of Sustainable Engineering*, Springer, 2013
- Grant M., Shreck A., Buchmann N., Tackling Food System Challenges through Experiential Education: Criteria for Optimal Course Design, *GAIA*, 2018, 27, 169-175
- Hadorn G.H., Biber-Klemm S., Grossenbacher-Mansuy W., Hoffmann-Riem H., Joye D., Pohl C., et al., The emergence of transdisciplinarity as a form of research, In: Hadorn G.H., Biber-Klemm S., Grossenbacher-Mansuy W., Hoffmann-Riem H., Joye D., Pohl C., et al., (Eds.), *Handbook of transdisciplinary research*, Springer, 2008
- Ison R., Systems thinking and practice for action research, In: Peter W., Bradbury H. (Eds.), *The Sage Handbook of Action Research Participative Inquiry and Practice*, Vol. 2, Sage Publications, London, 2008
- Jahn T., Transdisziplinarität in der Forschungspraxis, In: Bergmann M., Schramm E. (Eds.), *Transdisziplinäre Forschung: Integrative Forschungsprozesse verstehen und bewerten*, Campus Verlag, Frankfurt/Main, 2008, (in German)
- Krainer L., Winiwarter V., Die Universität als Akteurin der transformativen Wissenschaft: Konsequenzen für die Messung der Qualität transdisziplinärer Forschung, *GAIA*, 2016, 25, 110-116
- Lang D.J., Wiek A., Bergmann M., Stauffacher M., Martens P., Moll P., et al., Transdisciplinary research in sustainability science: practice, principles, and challenges, *Sustain. Sci.*, 2012, 7, 25-43
- Lieblein G., Breland T.A., Østergaard E., Salomonsson L., Francis C., Educational perspectives in agroecology: steps on a dual learning ladder toward responsible action, *NACTA Journal*, 2007, 37-44
- McGregor S.L., Transdisciplinary Pedagogy in Higher Education: Transdisciplinary Learning, Learning Cycles and Habits of Minds, In: Gibbs P. (Ed.), *Transdisciplinary Higher Education*, Springer International Publishing, 2017
- Meadows D.H., *Leverage points - Places to Intervene in a System*, The Sustainability Institute, The Sustainability Institute, VT, 1999
- Méndez V.E., Bacon C.M., Cohen R., Gliessman S.R., *Agroecology: A transdisciplinary, participatory and action-oriented approach*, CRC Press, Boca Ranton, 2015
- Merck J., Beermann M., The Relevance of Transdisciplinary Teaching and Learning for the Successful Integration of Sustainability Issues into Higher Education Development Integrative Approaches to Sustainable Development at University Level, Springer, Heidelberg, 2015
- Mitrany M., Stokols D., Gauging the transdisciplinary qualities and outcomes of doctoral training programs, *J. Plan. Educ. Res.*, 2005, 24, 437-449
- Mittelstraß J., Methodische Transdisziplinarität, *Technikfolgenabschätzung - Theor. Praxis*, 2005, 14, 18-23
- Muhar A., Visser J., Van Breda J., Experiences from establishing structured inter-and transdisciplinary doctoral programs in sustainability: a comparison of two cases in South Africa and Austria, *J. Cleaner Prod.*, 2013, 61, 122-129
- Nash J.M., Collins B.N., Loughlin S.E., Solbrig M., Harvey R., Krishnan-Sarin S., et al., Training the transdisciplinary scientist: a general framework applied to tobacco use behavior, *Nicotine Tob. Res.*, 2003, 5, 41-53
- Osgood C.E., The nature and measurement of meaning, *Psychol. Bull.*, 1952, 49, 197-237
- Parr D.M., Trexler C.J., Khanna N.R., Battisti B.T., Designing sustainable agriculture education: Academics' suggestions for an undergraduate curriculum at a land grant university, *Agric. Human Values*, 2007, 24, 523-533
- Reckwitz A., Toward a Theory of Social Practices A development in culturalist theorizing, *Eur. J. Soc. Theory*, 2002, 5, 243-263
- Ropohl G., Philosophy of socio-technical systems, *Techné: Res. Philosoph. Technol.*, 1999, 4, 186-194
- Schatzki T.R., Knorr-Cetina K., Von Savigny E., *The practice turn in contemporary theory*, Routledge, London and New York, 2001
- Scholz W.R., Tietje O., *Embedded case study methods: Integrating quantitative and qualitative knowledge*, Sage Publications, Thousand Oaks, 2002
- Steiner G., Posch A., Higher education for sustainability by means of transdisciplinary case studies: an innovative approach for solving complex, real-world problems, *J. Cleaner Prod.*, 2006, 14, 877-890
- Von Bertalanffy L., *General system theory: Foundations, development, applications*, George Braziller, New York, 1968