

## **Expedition Energy Transition**

### **Lessons learned from an educational co-creation experiment**

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*November 2016*

## **Background**

In September 2015 a call for proposals for educational innovation at the Eindhoven University of Technology was sent out by the 3TU.CEE (Center for Engineering Education of the three Dutch Technical Universities). At the Eindhoven Energy Institute (EEI) a proposal was developed to create an interdisciplinary educational program for both technical development and socio-economic embedding of sustainable energy innovations in society, Expedition Energy Transition. In November 2015 the proposal was approved and the experiment was held from December 2015 until July 2016. This report explains the setup of the experiment, provides an overview of the main outcomes and lessons learned, as well as an outline for future research and educational activities.

## Summary

To be able to fulfill our present and future energy needs, a change in our current unsustainable energy system is necessary: an energy transition. This transition requires a systemic approach that involves many stakeholders and that builds on new types of knowledge, tools and skills. The university can play a leading role here by facilitating and encouraging processes of co-creation with outside parties and educating (future) energy professionals who will have the skills and competencies to act as change agents. Currently, the TU/e is not yet equipped with appropriate curricula and staff to educate these engineers of the future. To fill this gap, we developed the Expedition Energy Transition, where we applied, in an experimental setting, co-creation in the context of energy transition in a university setting. Students of a multidisciplinary team, proposed their own innovative project that aimed to solve multiple societal challenges related to the energy transition and had to consider its advancement by means of various transition and management approaches.

Expedition Energy Transition was held from January until September 2016. Members of student team FAST that is developing a bus on formic acid as alternative to electric or fossil driving ([www.teamFAST.nl](http://www.teamFAST.nl)), took part in the experiment and defined 'a driving formic acid fueled bus at the end of 2016' as their energy transition challenge. During the Expedition, co-creation was not just applied as educational approach during the workshops but also more in general when developing the program together with practitioners, scientists, educational experts and students. The final program was composed of 7 workshops: (1) Open Space Studio, (2) Marketing, (3) Finance, (4) crowd funding, (5) barriers, (6) strategic niche management, and (7) business modeling. Set-up of the workshops (with the exception of workshop 2 and 3) were based on co-creation and networked learning approaches. Workshops 2 and 3 had a more traditional lecture like style, but were inserted into the program to the wishes and needs of the students (co-creation of program). The learning outcomes of the different workshops and the Expedition as a whole were evaluated using reflective notes and a focus group.

Overall, the Expedition Energy Transition was considered a success by students as well as teachers, experts and practitioners. Quote expert: "They learn to discover themselves and to understand the importance of context, stakeholders, interest and end-users to place your idea into the 'outside world'". Quote student: "It's nice to collaborate with people, since by listening to others you get more and more ideas and inspiration". At the end of the Expedition, students created a roadmap, including milestones and responsibilities, carried out a very successful crowdfunding campaign, and developed several business models and strategies for future adoption of the technology, including the formation of a niche, and mapping the different barriers. Moreover, teachers and trainers indicated that the students were very well prepared and were able to systematically analyze complex problems.

By experimenting this new approach, we also learned some important lessons that are important for future implementation of co-creation and networked learning in the educational program of the TU/e. Most importantly, we need a good method to catch the lessons learned during the different workshops and the result of their implementation in the project. Preferably we organize this in an iterative way. Additionally, an assessment tool should be developed to monitor student performance during the project. Furthermore, co-creation requires an extensive coordinator role, and a good training of teachers and coaches into the principles of the approach and the different teaching methods that can be applied.

## Table of Contents

Background.....	- 1 -
Summary .....	- 2 -
1. Motivation for the expedition.....	- 4 -
2. Educational approach.....	- 5 -
2.1 Co-creation .....	- 5 -
2.2 Networked learning.....	- 6 -
2.3 Diamond structure ('spekjesstructuur') .....	- 7 -
2.4 Lego Serious Play .....	- 8 -
3. Aim and set-up of the Expedition .....	- 9 -
3.1 Aim and learning objectives .....	- 9 -
3.2 Set-up of the workshops .....	- 9 -
4. Organization and Teaching.....	- 15 -
4.1 Coordination.....	- 15 -
4.2 Coaching and Teaching.....	- 15 -
5. Learning Outcomes .....	- 17 -
5.1 Reflective notes .....	- 17 -
5.2 Comments of teachers .....	- 19 -
5.3 Comments of experts .....	- 19 -
5.4 Focus group .....	- 19 -
6. Conclusions and most important lessons learned .....	- 22 -
7. Follow up.....	- 24 -
8. Dissemination.....	- 26 -
Bibliography.....	- 27 -

## 1. Motivation for the expedition

One of the grand challenges our society is facing today is its unsustainable energy system. We need a major shift in the way we fulfil our energy needs: an energy transition. Such a transition requires a systemic approach that involves many stakeholders and that builds on new types of knowledge, tools and skills. Furthermore, this transition implies a need for shifting the role of the university towards facilitating and encouraging processes of co-creation with outside parties, and educating (future) energy professionals who have the competences to act as change agents.

Over the last years researchers from the System Innovations and Sustainable Transitions group (School of Innovation Sciences, TU/e) have been working with sustainability professionals in the Netherlands and abroad to support them with the necessary knowledge, tools and skills to act as change agents. Here, researchers build on academic knowledge in the field of transition studies and business models combining broader perspectives on societal, systemic and company-level. This knowledge base is continuously advanced and new insights emerge from a great number of research projects initiated by the System Innovations and Sustainable Transitions group (School of Innovation Sciences) and the Innovation, Technology Entrepreneurship and Marketing group (school of Industrial Engineering). This requires different teaching methods based on co-creation methodologies, allowing participants to create together solutions for future adoption and up-scaling of their innovations, including both technical and socio-economical elements in their design. This educational program, Expedition Energy Transition, aimed to apply such co-creation methodologies, with lecturers serving as coaches rather than pure knowledge providers, to a university setting. Students worked in a team on an energy transition challenge, and proposed their own innovative practice based project or idea that addresses one or more of the societal challenges in the field of energy. They had to consider its advancement by means of various transition and management approaches. Student team FAST that is developing a bus on formic acid as alternative to electric or fossil driving, fitted into these boundary conditions and was willing to pioneer this methodology together with us<sup>1</sup>. At the start of the expedition, they defined ‘a driving formic acid fueled bus at the end of 2016’ as their energy challenge.

This report describes and evaluates the Expedition Energy Transition program. The report starts with an explanation of the applied educational methods, including co-creation and networked learning in chapter 2. Chapter 3 describes the set-up of the Expedition, the learning objectives and gives an overview of the workshops that were given. In chapter 4, the roles of teacher, coaches and coordinator is further explained. The program is evaluated in chapter 5. Main outcomes of and most important lessons learned during program are summarized in chapter 6. The report ends with suggestions and ideas for follow up of the program, and possible applications of the co-creation and networked learning methodologies in other educational activities.

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<sup>1</sup> see [www.teamfast.nl](http://www.teamfast.nl) for more information.

## 2. Educational approach

To reach the major aim of applying co-creation in the context of energy transition in a university educational setting, students built on knowledge and skills from the field of transition studies and business models to identify new solutions and ideas for their proposed innovation. Lecturers, practitioners and experts acted as coaches by guiding the process, asking specific questions and provide knowledge and information based on input of the students during the workshops. More specifically workshops typically started with the definition of the problem, then students had to come up with their own ideas how to solve this after which the theory was introduced and students had to complement and/or adapt their solutions. This approach contrasts with traditional education approaches, where knowledge transfer is mostly based on sending information from the expert towards the student. To accomplish this activating and creative way of learning, we made use of existing approaches: co-creation, networked-learning, diamond structure and Lego Serious Play. Although these approaches are not new per se, it is the first time that they were applied together for teaching activities at the TU/e.

Moreover, in June 2016 coaches attended a workshop organized by the 4TU Centre for Engineering Education (4TU.CEE) to expand their knowledge on active collaborative learning. In this workshop Professors Gerhart and Carpenter from Lawrence Technology Institute, Detroit, USA, explained educational approaches that could also be beneficial in co-creation workshop settings. We used this information as inspiration for the development of our own workshops. (For more info visit the 4TU.CEE website:

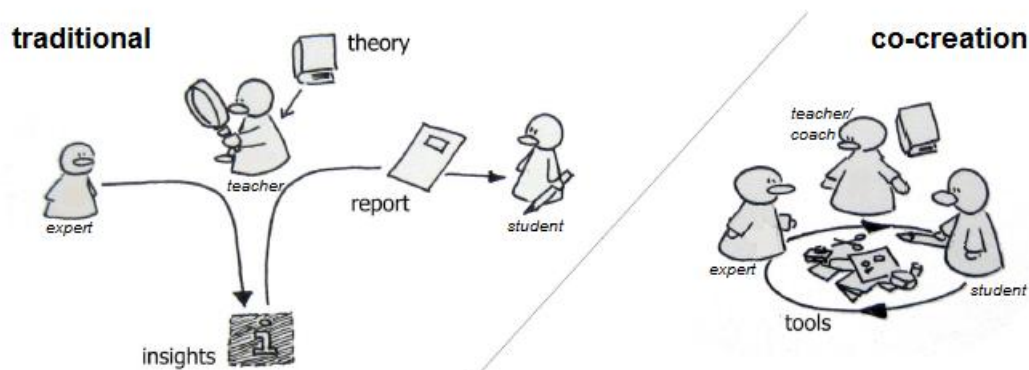
<https://www.4tu.nl/cee/en/news/!/1149/Carpenter%20and%20Gerhart%20workshop%20inspires%20education%20staff/>).

### 2.1 Co-creation

“Co-creation happens in the space between people” (Skills&Co, 2016).

Originating from marketing and design processes, co-creation aims at combining the ideas of different stakeholders e.g. users, companies, designers) and bring those ideas to a next level to mutually develop a new concept or product (figure 1) (Sanders & Stappers, 2008). When applied to education, co-creation is focused on knowledge creation and designing a (plan to find a) solution to a problem. Co-creation involves students as well as experts, practitioners and scientists, all operating at the same level and with a shared goal. The concept not only provides an interactive and active learning environment, but also prevents teachers from sending information to students too early in the process. Moreover, it gives students a strong feeling of co-ownership, which positively affects their learning. Typically a co-creation process consist of the following steps:

- Problem definition
- Articulation of the question
- Determination of the aim
- Searching and finding a solution
- Evaluating and adapting the aims and solutions in an interactive process



**Figure 1.** Schematic representation of the roles in the classical students, teachers and experts in the classical educational approach (left), and in a co-design/ co-creation set-up (right). Adapted from Sanders (Sanders & Stappers, 2008).

Co-creation requires participants to be aware of their individual role in a group as well as the shared outcomes that can be achieved (Interview Matt Clarke, KIC InnoEnergy, January 2016). As an analogy one can think of a football team scoring a point or an orchestra playing a song together. Therefore, it is important for teachers to pay attention to both individual contributions and the group process, as well as activities during workshops that focus on knowledge creation.

Within the Expedition Energy Transition program co-creation was applied on 2 levels:

1. A general level: the program was developed and co-created together with experts, practitioners, scientists and educational experts, following the needs of the students to give them a sense of ownership of and responsibility for the educational trajectory as well (i.e. workshops 2-7 were based on the outcomes of the Open Space Studio (workshop1)).
2. An educational approach: during the workshops, focusing on team building or content development

To stimulate and coach the process of co-creation, different teaching methods were applied, based on the methods that are used and developed for the transition studies courses for professionals (e.g. ABC brainstorm, idea wall, time pathway, world café). During the first workshop team building assignments were done. However, since the team was already in place before our experiment and performed well as a team, we did not repeat these in the other workshops but rather focused on content development. An overview of these methods can be found at the Innovation Map of the Expedition Energy Transition at the 4TU.CEE webpage: <https://www.4tu.nl/cee/en/research-innovation/>, under downloads. Appendix I provides a detailed overview of the different workshops, including the educational approaches used.

## 2.2 Networked learning

When people form a group to learn together, we speak of 'social learning' (Vrieling, et al., 2016). In the context of education social learning can be defined as "undertaking (a series of) learning activities by teachers (and students) in collaboration with colleagues, resulting in a change in cognition and/or behaviour at the individual and/or group level" (Doppenberg, et al., 2012). Networked learning is a perspective on social learning that describes how participants learn through communication, exchange and connections. People in a person's network can be seen as a source of knowledge (Siemens, 2004). Learning in networks can be informal (a chat during a break) or formal (attending a group training), and the networks themselves can be formal (a taskforce) or informal (talking to a student's parent). An additional characteristic of networked learning is sharing problems and insights in a constructive way, connecting with familiar concepts and using new knowledge that is collaboratively constructed

through *dialogues* and *social interactions* (Wenger, et al., 2011). Networked learning thus resembles co-creation, however with a strong emphasis on learning and sustainability of the network. This resemblance is also shown in the steps involved in Networked learning as a learning approach:

1. Problem definition (what is this network about?)
2. Determination of shared learning goals (what do we want to learn?)
3. Definition of a learning agenda (which knowledge do we need to achieve the learning goals?)
4. Inventorization of knowledge (who already something about this subject?)
5. Outward view (which expertise can we get from our larger network?)
6. Definition of plan to action (how can we get to this expertise?)

In our workshops we coached students by identifying knowledge gaps and supporting them in their strategy formation for dealing with particular issues, keeping the theory of business modelling and transition studies in mind. We started with asking questions and making an inventory of what students knew, instead of sending theory beforehand. For some workshops (barriers, crowdfunding) we also invited an expert from the field to help the students by providing input from their own practical experience.

### 2.3 Diamond structure ('spekjesstructuur')

Based on the networked learning approach we developed a 'diamond structure' approach to combine theory and practice (figure 2). In the first part, a coach with a scientific background helps to guide students towards an overview of critical areas and questions that should be considered for developing a plan of action, hereby building on the theory from business modelling and transition studies. Together with this coach students identify these areas and come up with some first ideas to tackle the different challenges identified (divergence). These ideas are then further tested and refined with the help of an expert from the field (convergence). For both the crowdfunding and the barriers workshop an expert from the field was invited to reflect with the students on their ideas. For other workshops students build on practical experience from the coach (i.e. double role for the coach) as well as their own expertise. Students were also encouraged by the coach to think about experts from the field that they could contact after the workshop to further reflect on and refine their ideas. This methodology is also similar to the design science method developed in the ITEM group of the TU/e in which hypotheses are built from literature and further tested and refined in practice (Burg, et al., 2012).



**Figure 2.** Schematic representation of the diamond structure approach, in which students diverge on their problem by identifying areas and identifying challenges and questions with the help of a coach/ scientific expert. By refining and testing their ideas with the help of an expert from the field, the problem is again converged.



### **2.4 Lego Serious Play**

Using Lego bricks as a tool enables students to reach a deeper understanding of the phenomenon at hand through hands-on and minds-on learning (LEGO Serious Play, 2016). Lego blocks can be used to build (scale) models but can also be used as metaphor. Lego facilitates both the individual and group contributions, thereby stimulating the co-creation process, and supports making connections between different elements and visualizing the strengths and weaknesses of a system. The Lego Serious Play method has been applied during workshop 7 on business models and ecosystems, as a tool to develop different business models for the Formic Acid technology.

### 3. Aim and set-up of the Expedition

#### 3.1 Aim and learning objectives

The aim of the Expedition Energy Transition program was to apply co-creation in the context of education for stimulating energy transition. The program is built around a practical project or idea, selected by the students themselves, that aims to address a societal challenge related to energy by exploring both the technical (prototype building) as well as social (system innovation and business) aspects of the innovation. Since these both aspects are intertwined, interdisciplinary learning and collaboration is not only stimulated, but also necessary to make the project a success. Learning objectives of the program were defined as follows and built on competences for stimulating transition processes identified by transition researchers (Sterrenberg, 2016):

After completion of the course students:

1. Can identify and reflect on the major social challenges related to the energy transition in various economic and political contexts.
2. Can use 'integrative' competencies to analyze and deal with societal and institutional aspects of energy technologies in a self-developed project. The competencies include a.o.:
  - a. Systemic, foresight and strategic thinking;
  - b. The ability to collaborate with scholars from different disciplines (interdisciplinarity) and practitioners (transdisciplinarity);
  - c. The ability to monitor, reflect and adjust the assumptions and the process.
3. Can create and implement a new business model for the selected technology;
4. Have created a prototype of the selected technology.

The program originally aimed at a group of 10-15 master students from various disciplines. Team FAST formed a slightly larger group of students (22); subgroups were selected (by the students themselves) for the workshops. Main disciplines in team FAST are management, marketing and PR, electrical and chemical engineering, external relations and finance, and future adoption (teamFAST, 2016). Students follow different BSc programs on the TU/e. Team FAST already worked as a project team before the onset of the Expedition, and therefore already had a clear and quite well defined energy transition challenge and group structure at the start of the experiment.

#### 3.2 Set-up of the workshops

The program of the Expedition Energy Transition was completely built on co-creation methods. This means, we created the program around the questions and aims that the students defined themselves, under supervision of a coach. To stimulate creative thinking and active learning, most educational activities had a workshop structure, in which we applied the co-creation methodologies previously used for the professional trainings and found during the expedition (e.g. Networked Learning Approach). An exception of this concept were workshop 2 and 3 (marketing and finance) that were coupled to regular educational activities at the TU/e and consisted of lectures only (see paragraph 3.2.2 and 3.2.3, and Appendix I).

The program started with a co-creation session in which the members of team FAST developed a strategic plan and defined responsibilities, tasks and related milestones (Open Space Studio). Based on the outcomes of this workshop, the program of the Expedition Energy Transition was further designed and co-created with the students along the way. A short overview of the program is given here, a detailed overview of the workshops can be found in appendix I. After each workshop, students were asked to fill in a short reflective note (see chapter 5.1 and appendix II). Appendices can be found in a separate document. Content of the different workshops is only shortly touched upon here. Those who are interested can get more information at Boukje Huijben ([j.c.c.m.huijben@tue.nl](mailto:j.c.c.m.huijben@tue.nl)) or Mieke van Marion ([m.h.v.marion@tue.nl](mailto:m.h.v.marion@tue.nl)).

### 3.2.1. Open Space Studio

January 11-12, 2016

The two day co-creation workshop in de Koningshof conference center in Veldhoven was meant to create a strategic plan for team FAST that would help identify core areas to work on as well as division of responsibilities and tasks and related milestones (figure 3). (The workshop was preceded by a session in which the team defined their goal. This session took place before onset of the Expedition). The workshop was organized by Claudia Depenthal and Matt Clarke of KIC InnoEnergy. Next to more content wise exercises to create a strategic plan and new team structure the coaches included a number of assignments to make participants aware of their individual roles in the team and to build better connections. For example, in the introduction round participants had to introduce themselves and describe how they were feeling that day and what was on top of their mind.

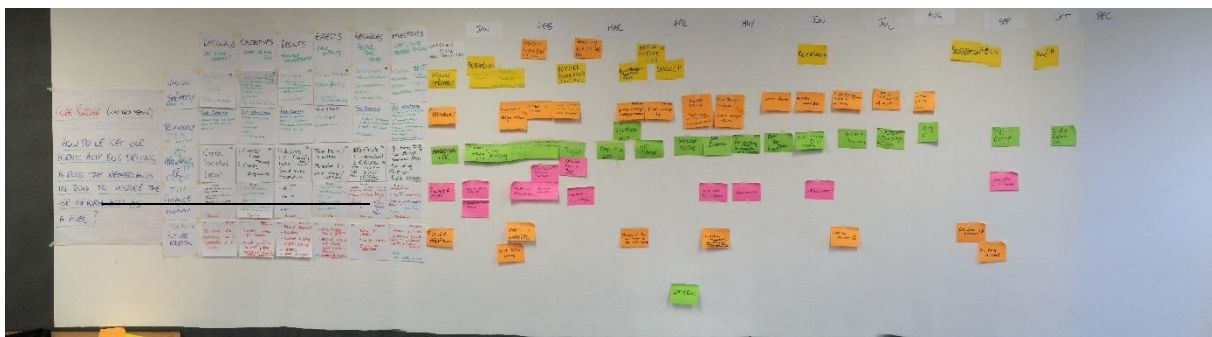
In another exercise students had to discuss in pairs (multiple rounds, with positive attitude):

“In this team, I am contributing....”

“In this team, you are contributing....”

“If we want to move forward, we have to....”

These type of exercises have been applied in professional education settings and can also be found in networked learning (e.g. ‘complimentenregen’ method in network learning toolkit). They help to create a relaxed and open atmosphere in which participants feel equal, which is a very important prerequisite for co-creation in groups (Skills&Co, 2016).



**Figure 3:** Output of the Open Space Studio Workshop: a strategic plan for team FAST, including core areas to work on, responsibilities and milestones. Rows represent the key areas of the team (e.g. vision, technology, and marketing); columns represent the interpretation of these key areas (e.g. results, effects, resources, milestones); the colored post-its represent the time planning per key area, including the different tasks and milestones.

### 3.2.2. Marketing

March 16, 2016

Half a day of lectures on marketing aspects by Prof. Ed Nijssen (Innovation Technology Entrepreneurship and Marketing, TU/e). Students were included in the ongoing CTEM course (business plan development course).

### 3.2.3. Finance

April 22, 2016

Half a day of lectures on financial issues for new venture development by Sharon Dolmans. This workshop was also part of the CTEM course and again traditional in terms of educational set-up.

*Note: Co-creation was not applied as educational approach during the Marketing and Finance workshops. However, these workshops were included in the program based on the questions and needs of the students. As such they form part of the development of the program which was co-created together with the students.*

### 3.2.4. Crowdfunding

*Preparation session:* March 18, 2016

Exploring the different elements of a crowdfunding campaign according to the crowdfunding canvasses of Douw and Koren consultancy (Douw&Koren, 2016). Students were first asked to come up with a list of critical elements individually. During the workshop, an idea wall (figure 4) was used to group and discuss their findings, after which missing items were introduced by the workshop coach. In the next round students discussed what they knew about the different elements (i.e. ideas for execution) and who could help them out. This was used as a basis for a discussion with crowdfunding experts.



**Figure 4:** Example of an idea wall during the crowd funding preparation session. All students individually put down their ideas on post-its. The ideas are then categorized and discussed within the group, after which under supervision of a coach the missing elements are filled in.

**Expert session 1:** March 22, 2016

Discussing the different building blocks for a crowdfunding campaign with an expert of Douw and Koren (checking of ideas). Based on this session a project plan was made for execution of the crowdfunding campaign. This was further validated in a second expert session.

**Expert session 2:** April 20, 2016

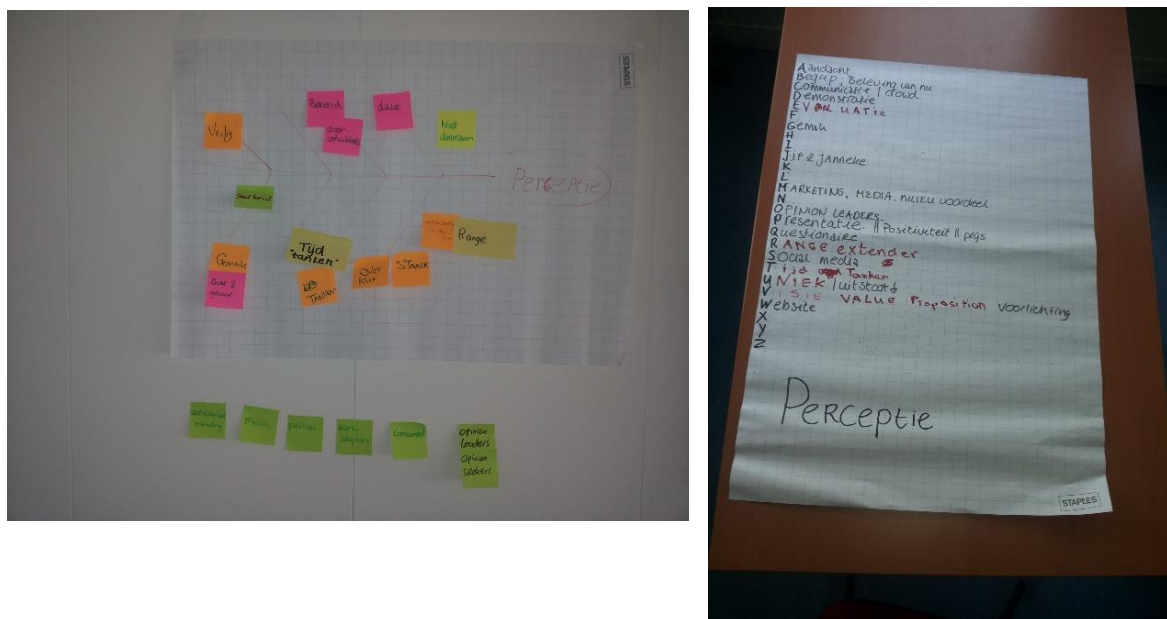
Final check of the crowdfunding plan with two experts of Douw and Koren consultancy.

*Note: In July 2016 the crowdfunding campaign of team FAST was successfully finished (July 6, 2016: €10739 funded, 108% of the target).*

### 3.2.5. Future adoption: Barriers

April 14, 2016

In this workshop we introduced the Multi-Level Perspective and focused on the regime level which consists of different dimensions such as infrastructures, rules and regulations and user practices (Geels, 2002). The different dimensions were not introduced beforehand, but built together with the students by following a set of questions and by guiding students towards missing elements. The different dimensions and related system barriers were analyzed using the fishbone method, as well as related actors. An ABC brainstorm was used to come up with a first set of solutions for these barriers (figure 5). The actor analysis was a first step to clarify who could help the team further in their development or was opposing their activities. A more extensive actor analysis assignment was done in the Strategic Niche Management workshop. In the second part of the workshop an expert from the field was present to support the students.



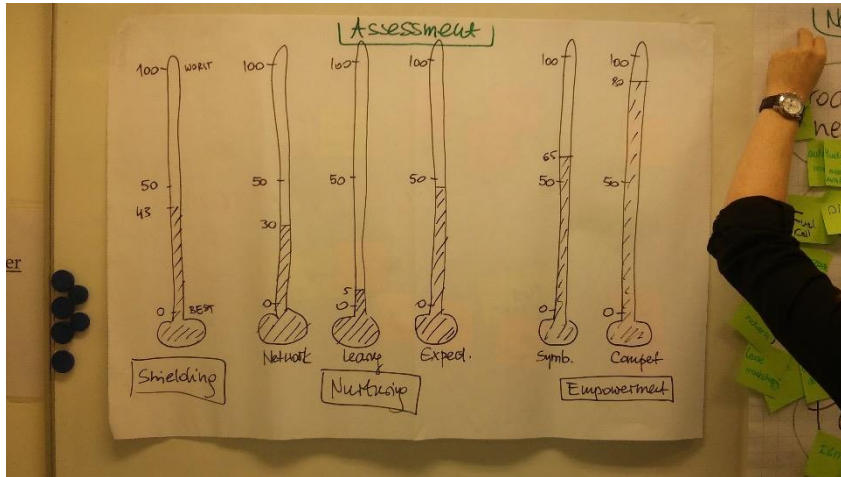
**Figure 5:** Output of the barrier workshop. Left: dimension ‘perception’, visualizing different barriers in a fishbone model, and indicating the different actors. Right: possible solutions from the ABC brainstorm.

### 3.2.6. Future adoption: Strategic Niche Management (SNM)

June 16, 2016

The Strategic Niche Management (SNM) theoretical perspective consist of three processes: shielding, nurturing and empowerment (Raven, 2012). Shielding refers to processes that enable the building of a protected space, nurturing to processes that support niche growth and empowerment to embedding of the niche in mainstream structures either in a symbiotic way (fit) or by altering mainstream conditions (stretch). In this workshop students developed strategies for the growth of the niche of their innovation following the SNM theory.

The workshop started with a series of questions and brainstorm sessions with the students (idea wall structure) after which the different theoretical elements were introduced. The workshop ended with an evaluation of how well the team performed on each of the SNM processes (figure 6).

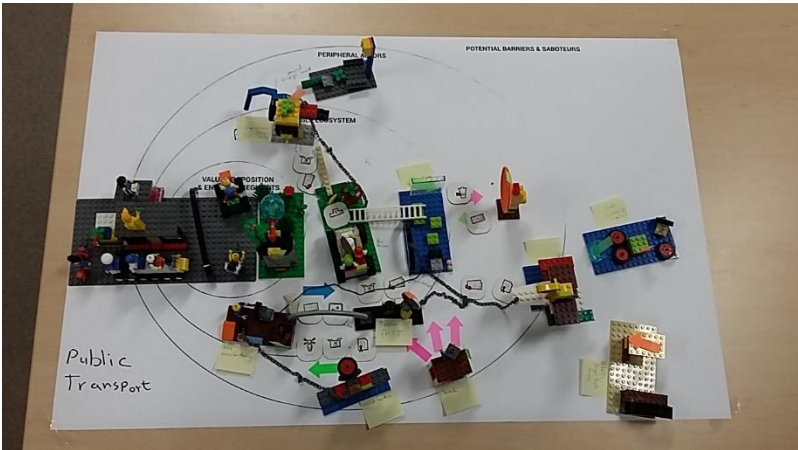


**Figure 6:** Outcome of the SNM workshop, giving a summary of the results on where the project stands in the three SNM processes: shielding, nurturing and empowerment.

### **3.2.7: Future adoption: Business Models and Ecosystems**

July 13, 2016

In this workshop, students worked on the development of a business model for their technology. Using Lego Serious Play as a workshop tool students developed different business models for a formic acid bus, a truck on formic acid, silent boats and a standalone generator. Next to students from team FAST we had 5 external people joining the workshop. A few warming up exercises were used to get to know each other and the Lego methodology (i.e. first build, then think along the way and co-create together). The business model was then built in different rounds by following a set of questions presented by the coaches. First, the end user and value proposition were being defined after which necessary ecosystem value chain actors were identified. After that peripheral actors were indicated and finally opposing actors. Actor strategies were also considered (i.e. willingness and ability to contribute to the delivery of the value proposition). Thereby a link to previous workshops was also made (e.g. actor analysis, fit/stretch strategies). The world café method was used so in different rounds participants switched tables to further build on ideas developed in previous rounds. For each table a facilitator was assigned to summarize the results of the previous rounds and to facilitate the group process. At the end of the workshop an overview of business model tools was presented and a movie was made so that students could use those as a reference to further develop their project. An example of a business model for use of formic acid in public transport is shown in figure 7. In the center, the end user and value proposition are displayed. The second circle represents the ecosystem value chain actors, and in the third circle the peripheral actors are displayed. The workshop ended with a short class providing an overview of business model mapping methods.



**Figure 7:** Business model for public transport on formic acid created with Lego Serious play. In the center, the end user and value proposition are displayed, the second circle represents the ecosystem value chain actors, and in the third circle the peripheral actors are displayed. Connections between all different elements are clearly visible.

## 4. Organization and Teaching

In this chapter we elaborate on the different roles that are involved in an educational co-creation set-up: coordinator, teacher, and coach. Table 1 gives an overview of these different roles, including the most important key elements and strategies.

### 4.1 Coordination

During the Expedition, we experienced that co-creation requires extensive coordination. Students, coaches, practitioners, scientists and educational experts have to be brought together, the educational activities have to be (re)constructed, contact with new teachers or experts has to be made, and workshops have to be organized. It is therefore important that one central person has overview and stays in contact with all different subjects and stakeholders. Compared to traditional ways of teaching, coordination of co-creation is much more intensive, and is also more intensive than for example the coordination of design based learning (DBL) project of the regular curriculum of the TU/e. For the Expedition Energy Transition, approximately 2-4h per week were spent on practical coordination (rooms, materials, contacting teachers/experts etc.), depending on the number of students, experts and practitioners involved, and 4-10h per week for content related coordination (adjust content of different teachers and experts), depending on the involvement of other teachers. When applied to regular educational programs, it is important to allocate sufficient time and financial resources for coordination. The practical coordination does not necessarily have to be executed by someone with substantive domain knowledge. However, knowledge of transition studies, business models, co-creation and activating educational activities is a prerequisite for content and didactical development of the course.

### 4.2 Coaching and Teaching

Co-creating education primarily means that teachers act as (content) coaches and let students discover the matter themselves. It is therefore important that teachers prevent themselves from sending information to students too soon. Therefore, focus is on building a learning process, rather than on preparing lecture slides. Here, you can think of developing methods to introduce (new) topics, defining stimulating questions, developing and preparing activating educational approaches, and preparing supporting information (e.g. slides, reader). It is important to have a good inventory of the knowledge base behind the course, hold on to this during the learning process, and continuously evaluate and give feedback both on content and process. During the Expedition Energy Transition, feedback of students was gathered using reflective notes (van den Beemt & Vrieling, in preparation) at the end of each workshop.

An important aspect of teaching in co-creation is coaching. The role of the coach is to oversee the group process (equal contribution of all group members, equal distribution of tasks, equal learning results), guide discussions, make sure students keep their focus and define clear (sub) goals, but are also open enough for new ideas, and guide and assess (together with teachers/ subject specialists) the output the students created. This means that, although coaches do not have to be subject specialists, some content knowledge (in our case on business modelling and transition studies), and the ability to stand 'above' the matter, is required. Furthermore, coaches need to be familiar with co-creation and activating educational approaches. During the Expedition, the role of process coach and teacher were combined by the teachers of the workshops.

Co-creating education requires extensive coordination, process coaching and customized teaching. Because co-creation is a dynamic process, the results and follow-up may change every moment, both on the program level and during the workshops/ lessons. This requires adaptation of all stakeholders involved, which also means that, when applied to regular educational activities, the educational set-



up changes per year/ period the course is given. Although some subjects can be anticipated, and some steering is possible as well, part of the educational set-up and content has to be created and developed on the way. Moreover, to guarantee the process of co-creation and equal individual contributions, we think that groups should not exceed 15-20 students. Altogether, this shows that co-creation involves a relatively high workload and is difficult to apply to larger student groups. However, our approach also results in interdisciplinary learning and learning of new skills on which is much less focus in regular education. As a follow-up of the Expedition Energy Transition, we are now developing educational modules that can be combined or followed independently. On the one hand, this gives the freedom for students to create their own program, but on the other hand, it provides a basic set of workshops/ educational activities for teachers and coordinators to build on.

**Table 1: overview of different roles of educational co-creation, and their key elements and strategies.**

role	Key elements/ strategies
<b>Coordinator</b>	Practical coordination (rooms, teachers, materials): 2-4h per week Content coordination (content adjustments between different teachers, workshops): 4-10h per week Knowledge of content and didactical elements Helicopter view: link between students, teachers, coaches and experts
<b>Teacher</b>	Focus on building a learning process Prevent sending information to students too soon Good knowledge inventorization at start of workshop/ course Continuous evaluation and reflection of knowledge and goals
<b>Coach</b>	Guide group process Facilitate/ catalyze discussions No expert, but enough knowledge to stand 'above' the matter Good background in co-creation and coaching

Note: the role of teacher and coach can be combined.

## 5. Learning Outcomes

The Expedition Energy Transition program has been evaluated using different methods. The learning outcomes as well as the perception of students of the workshops were evaluated directly after most workshops by means of reflective notes. Additionally, the Expedition was evaluated on content, process, and educational approaches during a focus group session. Finally, teachers, coaches and experts were informally asked to put down their experiences on paper. The following sections discuss outcomes of these evaluations.

### 5.1 Reflective notes

The outline of the reflective notes can be found in Appendix II. In Appendix III a summary of the most important findings is given. Students were asked 3 questions:

- Which question did you bring to the workshop?
- What happened during the workshop? How did you experience that? What contributed to that experience?
- What is the most important thing you've taken from the workshop (tips, tools, new connections etc. but also inspiration, new insights). Give an example.

All students present at the workshops filled in the reflective notes. Note however, that participation in the workshops was voluntary, and that different students participated in the workshops. During the Expedition the set-up of the reflective notes slightly changed in order to reach deeper reflection of the students (Appendix II).

We analyzed the reflective notes at 3 levels:

- Content and skills related outcomes. What content and or skills did the student take from the workshop, and can we link that to the learning objectives we defined?
- Process related outcomes: what happened during the workshop?
- Perception: how did students experience the workshop?

#### 5.1.1 Content and skills

In general, all students were able to write down specific content related outcomes of the workshops. Some students even wrote down a few 'to-do' items that they want to work on the coming weeks (e.g. contact a certain person). This indicates they actually were able to apply the theory learned during the workshops to their own situation and define action out of that. On the other hand, most outcomes were not specific but were formulated rather vague, which indicates that more attention should be paid to the definition of lessons learned at the end of the workshops. Exceptions are the crowdfunding workshops that resulted in a very successful crowd funding campaign, and the LEGO Business model workshop where the set-ups of business models for four different formic acid applications were developed. Nevertheless, we think deep learning and application of the lessons can be reached, when students work in iterative way. Since involvement was voluntary, and different students attended the individual workshops, this was hard to achieve in the present set-up. For future application of the co-creation approach in education we should critically look at a good method to capture the lessons learned and build further on them in subsequent meetings, preferably in an iterative way.

Next to content related outcomes, students also took other lessons from the workshops. Some specific outcomes were: (1) getting different view on the subject matter due to people outside the sub team, (2) inspiration and/or motivation, (3) tools, (4) new ideas, and (5) collaboration, listening to others. As expected, these non-content related lessons were only learned during the interactive and co-creative workshops, and not during the more traditional lectures (marketing and finance). This underlines our idea that co-creation methodologies strongly contribute to the development of competences that are

necessary to be able to act as ‘change agents’. To get an individual and objective evaluation of these learning outcomes, we consider using peer review methods in future applications.

### 5.1.2 Process

With the exception of the marketing and finance workshop, all workshops used co-creation and network learning methodologies. Not surprisingly, the outcomes of the reflection notes show that, although the marketing (and finance?) workshops gave a good overview of the theory, they had too much a lecture style and students would prefer a more interactive way of teaching. This is in contrast to the other workshops that were evaluated as much more interactive. Students describe the crowdfunding preparation session as a brainstorm session in which ideas, people and topics were combined at the end of the workshop. This resulted not only in answers, but also in many new questions, which they could bring to the next session with an expert. Quote: “we used many post-its to write down ideas, then grouped them and created a roadmap”. The expert session mainly gave answers to their questions and tips for their plan of action, but nevertheless also here the interaction and “sparring” with team members was highly appreciated. The Barriers workshops was described as instructive, and learning to analyze the problem from different angles. Quote: “by zooming in and out there is constantly new input to think about. The workshop strategic Niche Management was described as very interactive, free coaching but with guidance when needed. Quote: “nice interchange between lecture and interaction”. This stresses the important role of the coach during the sessions that on one hand has to activate the students and give them freedom to come to solutions themselves, but on the other hand should give new information and actively guide the learning process. Moreover, it indicates that a good balance between student input and guidance and information sending by the teacher/ coach is important. As some students (mainly technical background) indicated at the crowdfunding preparation session and the barriers workshop, too much freedom was not much appreciated and gave them the feeling of too long and exaggerated brainstorms and/or overanalyzing the problem. This could be avoided by a homework preparation of the first steps of the network learning method.

The LEGO Business model workshop was evaluated as fun, creative but also sometimes chaotic. LEGO helped in starting quickly, visualizing the issues, shifting in ‘real-life’, making connections, and thinking out of the box. Students liked to work/ build further on the ideas of the others groups (world café method). External people that were involved in the workshop indicated that the Lego works very well as a tool. Quote: “Set-up ensures collective learning and double loop learning”. However, although the workshop is based on business modelling theories, application and integration of other theories like transition studies was now largely missing, also due to different student constellations over the different workshops, and would require more guidance and deepening of the subject matter in future editions.

Interestingly, students indicated at all workshops that they learned a lot from the knowledge or view of other team members. Quotes: “It’s nice to collaborate with people, since by listening to others you get more and more ideas and inspiration”, “Got again another view by people outside my own sub team”. This underlines the effectiveness of the network learning methodology.

### 5.1.3 Experience

In general students had a very positive view on all workshops. Next to content and skills they got inspiration and motivation from the workshops. Although not intended like that, the LEGO workshop was even perceived as teambuilding. The LEGO workshop also attracted the highest number of students, and students with a more technical background, which helped to get everyone involved in the learning process and to come.

In all workshops we aimed to build further on the knowledge the students gained at the prior sessions. Since the student participated on a voluntary basis, and student constellation were different between the workshops, some repetition of the previous workshops was needed. However, students perceived

this as too much. Some students also indicated that they could have learned more or that the workshop could be shorter, whereas others were much more positive, or even stated that they learned a lot. These different perceptions may also be caused by the different student constellations (some student followed the whole program whereas others just picked one or 2 workshops), and different background of the students (some theory may have been discussed during their regular studies). For future application of the methodology it would be interesting to map the differences between students before and after the program (e.g. by using a beta mentality model, [www.betamentality.nl](http://www.betamentality.nl)) to see whether there is a clear difference in their views and whether these change due to the program.

It is important to note that during the Expedition we worked with students that already worked as team before and were well attuned to each other (both content and process wise), and moreover had a very high intrinsic motivation. When applied to regular educational activities these aspects should be well monitored, and probably require more teambuilding and process coaching. Here, we could also build on the networked learning tool, to monitor and guide the process where needed.

### **5.2 Comments of teachers**

Teachers of the Lego Serious Play business model workshop indicated that Lego is a very visual and 3 dimensional tool to represent business models. Students were much activated and involved and continued building new objects during the whole workshop, which was exactly what was aimed for. Content wise, students were well able to see the perspectives of different actors in the ecosystem. Process wise all participants were treated equal and were able to contribute equally. Interestingly, although the more technical students were less (or not at all) familiar with the subject, they felt more involved in the workshop through using Lego, and were equally able to express themselves clearly. Teachers also indicated that there should be some follow-up for the students to be able to provide more details on business modelling for the students, which was missing now.

### **5.3 Comments of experts**

Practical experts valued the deep level of preparation of the students and the systematic way of analyzing the complex problems of radical sustainable innovations. Quote (Douw & Koren crowdfunding agency): "They were very well prepared and professional".

Expert Ben Rutten (program manager Strategic Area Energy TU/e) indicated that the Expedition Energy Transition program is very valuable to provide students with awareness. They learn to discover themselves and to understand the importance of context, stakeholders, interest and end-users to place your idea into the 'outside world'. They learn to find their own ways in this world to strengthen your idea, either using or get around the current interests. The structural way this is taught to the student in the Expedition Energy Transition helps, accelerates and prevents that the team has to reinvent the wheel over and over again. He also advised to get involved more experts in future follow-up programs of the Expedition Energy Transition.

Students indicated that a proper preparation of the expert in the team goals and milestones is necessary. Input of experts was only considered valuable when the experts could directly discuss with them on the same level.

### **5.4 Focus group**

We organized a 1 hour focus group in which we discussed both process and content wise experiences of the students in the workshops. We selected 5 students from different sub-teams and included one

of the students that was responsible for coordination with the team. We defined question related to 4 themes: (1) co-creation, (2) network learning, (3) content and output, and (4) coordination (see Appendix IV). The main outcomes of the focus group are elaborated here, a detailed description of the outcomes can be found in appendix V.

#### **5.4.1. Co-creation**

As explained before, co-creation was applied during the workshops as well as in developing the program of the Expedition. From all workshops, co-creation was best experienced during the Open Space Studio workshop. This workshop also resulted in a mutually developed outcome: a strategic plan for the team. Although the crowd-funding workshops has been very useful for the team, and resulted in a successful campaign, students experienced too much guidance here, mainly in the preparation session. Students also indicated that the speed of the workshops could be increased (with exception of the LEGO workshop), and that the preparation sessions could be done individually at home, or offered in a more lecture style way. For co-creation both the individual and collective contributions of the students are important. Despite their different backgrounds, students felt that they could all contribute equally, and that all input was appreciated during all workshops.

During the Open Space Workshop the themes for the team to work on were defined and based on this the program of the Expedition was developed. This learning line has been discussed with the contact person of the team but was not well communicated with the other team members. Therefore, the team did not recognize their own themes, and had not really the feeling that the program was co-created. The change in student constellation between the different workshops also contributed to this perception.

#### **5.4.2 Networked learning**

Students often experienced the brainstorm session as too elaborate, which left little time to go deep into the subject matter. By preparing steps 1 to 4 (question articulation, set-up of learning agenda, and inventorying of knowledge) of the networked learning approach individually before the workshop we would be able to reach deeper level discussions during the workshop faster. Furthermore, step 6 of network learning method (plan of action) was insufficiently executed in the future adoption workshops. For crowdfunding the outcomes of the workshop were specific and could be more easily converted to a plan of action. Therefore, for future application of co-creation and network learning in an educational setting, we should (1) think about a good format to put the learned lessons into a practical plan of action, and (2) schedule more time during the meetings to create such a plan. Alternatively, students could set-up a plan of action themselves and we could discuss this in separately scheduled coaching sessions.

Students indicate that due to the workshops their network expanded, mainly inside the TU/e. The crowdfunding workshops contributed most to this, and resulted in many new contacts (a.o. crowd funders). This workshop also resulted in a different use of the network: supporting the campaign, but also actively take part by e.g. advertising. Next to expanding their network, networked learning also gave the students some new ideas to work on.

#### **5.4.3 Content and output**

Students have the best experience with the first workshop (Open Space studio). The whole team was present, the workshop was very interactive and had a concrete outcome (strategic plan). The crowdfunding workshops were also very useful, and resulted in concrete outcomes and action. The more traditional workshops Finance and Marketing have been experienced as less useful. Mainly because the match with the project content was less good. The scope of the future adoption track was not clear enough and the overlap between the workshops was perceived as too much. This track could be improved by clustering the workshops. One idea would be to have a first cluster of workshops with

basic information and then to have a second round of both reflection on the first round of workshops and how they implemented this in their project as well as deepening towards more refined strategies for implementation and up-scaling of their project. Clustering will also help to create a better link between the different elements.

Next to the entrepreneurial workshops, some students indicated that it would also be good to have some more technical based workshop (e.g. chemistry for marketing). This could for example be done by peer teaching methodologies. Peer teaching could also be applied to equalize the entry-levels of the students. The network learning method could be used to make an inventory of the present knowledge and the people that could contribute to peer the peer teaching. Teachers can be involved to check the individual contributions and the set-up of the peer sessions.

The most important lessons learned during the Expedition are (1) creating team structure ( Open Space Studio ) , (2) enlarged vision, (3) importance of a good communication, documentation and structure, (4) team FAST is meant for R&D, independent of the application and market, team FAST always plays the same role, (5) first build then engineer (from LEGO workshop). To improve the outcomes of the workshops it could help to use more the time-line that had been defined during the first workshop, to define more concrete action points, and by taking time for an extensive recap at the end of the workshops. Also a good format to update the other team members on the outcomes of the workshops is missing and would be very valuable.

#### **5.4.4 Coordination**

All teachers and trainers were evaluated as very valuable. On the other hand the role of the experts could be improved, and experts should only be involved if students have concrete questions when designing their plan of action (as was the case in the crowdfunding workshops).

The connection between the different workshops was not clear enough and could be improved by having a short discussion during both the introduction as well as the wrap up of the workshops. Furthermore, the sequence of the workshops should be reconsidered. One student suggested to have the business model workshop up-front and then to have the other workshops for deepening. In the individual workshops, the pace could be a bit higher, and the time pressure during the LEGO workshop was highly appreciated. We think however, that the pace should carefully be adjusted to the aims of the workshop. The LEGO workshop was more oriented towards idea generation than towards creating a more complete picture based on a particular theoretical framework where the latter requires more time for discussion.

During the Expedition, students picked the workshops based on their personal interests. It was interesting to see that the LEGO workshop attracted the more technical students of the group to join a workshop on business models. Quote (student technical team, team FAST, during the workshop): “I was triggered by the LEGO” (student technical team, team FAST). Nevertheless, students also indicated the importance of having a complete team to be able for everyone to contribute and more compulsory character is not considered a problem (e.g. subscription for a set of workshops). A better communication about the goals of the (set of) workshops would then be essential.

## 6. Conclusions and most important lessons learned

The aim of the Expedition Energy Transition was to transfer available academic knowledge and knowhow into practical contexts by using co-creation methodologies, applied on a social challenge related to energy transition. Members of student team FAST took part in the experiment and defined 'a driving formic acid fueled bus at the end of 2016' as their energy transition challenge. During the Expedition, co-creation was not just applied as educational method during the workshop but also more in general when developing the program together with practitioners, scientists, educational experts and students. In general, we consider the Expedition as a success. Members of team FAST created a roadmap, including milestones and responsibilities, carried out a very successful crowdfunding campaign, and were able to develop several business models for future adoption of the technology, strategies for the formation of a niche, and mapping the different barriers. Moreover, teachers and trainers indicate that the students were very well prepared and were able to systematically analyze complex problems.

By experimenting with this new methodology we also learned some important lessons that we list here.

- As teachers and coaches we experienced that co-creation and network learning not only help in preventing information to students too soon, but also give a strong feeling of co-ownership to the students, which positively affects their learning.
- Co-creation of a program requires an intensive coordinator role. The coordinator should have a helicopter view on all aspects and is the link between students, teachers, coaches, and experts.
- In co-creation, both the individual and collective contributions of the group are of equal importance. We used a combination of activating and interactive learning methods to accomplish this. In particular, the idea wall (writing individual contributions on post-its then group and discuss in the group), works very well in the group process and gives a voice to everyone. However, during the discussions coaches should monitor the students closely to prevent that the discussion is dominated by certain students.
- By preparing the first steps of the network learning process individually before the workshops, the first brainstorm session can be faster and more effective, leaving room for more in depth discussions.
- When working with different student constellations, clear rules about (mandatory) presence of all team members to (part of) the sessions should be communicated.
- LEGO Serious Play is a powerful tool to visualize issues, make connections, and dynamically adapt or improve the solutions. It can be easily combined with other interactive education methods, such as the world café. By working with metaphors, students from different disciplines and with different knowledge levels can quickly collaborate on the same level. When aiming for integration and application of different theories, more extensive coaching and combination with additional teaching methods is required.
- During the workshops, the possibility to develop and evaluate a concrete plan of action should be created. This would also involve the development of a method to capture the lessons learned during the workshops and the whole program, preferably in an iterative way. When working with different student constellations in the different workshops, a method to communicate the lessons to the other group members should be developed. Methods based on the SCRUM methodology could be applied here in an adapted manner. SCRUM is a framework to complete complex projects and to come to fast and better solutions (Schwaber & Sutherland, 2016).
- An assessment plan should be developed that allows for objective testing of the learning outcomes (both content and process related). To be able to give feedback on and assess both the individual and group contributions, the plan should include both intermediate and final,

and formative as well as summative assessments. Moreover, the plan should be able to differentiate between students from different backgrounds and knowledge levels (technical background vs. industrial engineering background).

- To improve learning and keep a clear focus, a clear line within the workshops should be created and well communicated with students as well as teachers, coaches and experts. This also includes the formulation of clear goals, per workshops, as well as for the whole program. On the other hand, the program should provide enough flexibility to adapt on the way.
- For evaluation purposes, reflective notes are very effective. However, to stimulate deep reflection of the students, the questions should be carefully posed and enough time should be scheduled to fill in the forms, preferably adjacent to the teaching activity.



## 7. Follow up

The success of the Expedition inspired us, and hopefully others, to think of new ways to apply the methodology to other educational activities. We list here our ideas, including boundary conditions that are important for follow up and future implementation of co-creation and network learning in a university setting.

- The Expedition Energy Transition program focused on entrepreneurship, marketing and future adoption of the technology. However, for a full development of a technological innovation a parallel trajectory focusing on technological development and/or theory has to run simultaneously.
- The basis of co-creation lies in the creation of an innovation from idea to product/solution. Active involvement of all group members is a prerequisite. Moreover, to stimulate network learning, a student population with diverse backgrounds is preferable. Therefore, educational co-creation is in particular interesting for relatively small, interdisciplinary groups of around 15 students, working on radical innovations projects. The time span of minimum 0.5 year or 1 semester should be kept to allow for executing of all steps of the learning process. Co-creation could be applied on all disciplines and is not confined to energy-related subjects.
- The strength of co-creation is to not only to apply it as teaching activity but also to develop the whole program together with, and to the specific needs of the students. This requires flexibility to adjust and develop the program on the way and also implies different programs per student generation and per chosen innovation. However, similar topics can be anticipated for different projects, and subtle steering is as well possible.
- Co-creation requires extensive coaching and a completely different way of teaching. The teaching and coordination load is expected to be higher than in traditional education methods, also when the program is well integrated in the curriculum and has run for several years. When the program as a whole is well developed and co-created, it can allow for some more traditional teaching activities, especially when these aim to provide basic knowledge. However, the primary base should be co-creation and alternatively basic knowledge can be provided by using network learning and/or peer teaching methodologies.
- The first workshop (Open Space Studio) has been outsourced to KIC InnoEnergy. Preferably we would also teach this part of the educational program in-house. This would require a training program for coaches/ teachers. The development of such a program could be part of a follow-up program of the Expedition. As dissemination of the Expedition we are organizing a train-the-trainers course on co-creation, which will take part in Jan/Feb 2017.
- The Expedition has run with members of team FAST, which already worked as team before the onset of the program, and also already had a defined innovation to work on. When starting with new student groups more time for team building, getting to know each other, and idea generation is required. This should be scheduled before the creation of the strategic plan and learning line, which was now done during the Open Space Studio workshop. To better monitor the team structure and performance, we could also make use of the network learning tool. Furthermore, we can built on the experiences we have in the bachelor honors program as well.
- Intrinsic motivation and collaboration of the students are very important aspects of co-creation. Working with team FAST meant that these characteristics were in principle present. When applied to more regular (and maybe even obligatory) educational activities these may need to be stimulated much more, and moreover may require a more confined time span. Nonetheless, integration of co-creation in DBL (OGO) projects or multi- or interdisciplinary projects of the university could contribute to the applied knowledge and professional development of the students. This would also fit in the strategy of the university to change the traditional educational activities for large student groups towards an active learning environment for smaller groups. An interesting new research question for a follow-up study

would be: How to integrate co-creation methodologies to group projects of the major curriculum of different faculties of the TU/e?

- When co-creation will be applied to regular teaching activities of the TU/e, requirements for embedding in the curriculum should be investigated, including coordination, responsibilities, capacity and costs.
- More concrete, the Expedition Energy Transition will be prosecuted by a master honors program which will be developed by the Strategic Area Energy in collaboration with the KIC InnoEnergy. Planning is to start this program in September 2017. To ensure mobility of the master students during the program we may consider investigating the use of online learning environments in co-creation.
- The Strategic Area Energy, ITEM and TIS research groups of the IE&IS Department of the TU/e are together developing an Innovation Camp on entrepreneurship and transition theory for PhD and PDEng students with a background in energy, mobility or smart cities. This program is partly based on the co-creation methodologies we applied in the Expedition Energy Transition. The courses comprises in total 10 ECTS and will be held in November 2016 and January 2017.
- In October a proposal for a second educational co-creation experiment, Expedition Energy transition – the next step, has been submitted to the 4TU.CEE federation. With this proposal, would like to bring educational co-creation and networked learning to the next level. To reach this goal, we will develop the necessary methods (i.e. a coaching trajectory, a method to capture the lessons the students learned, and an assessment method) required for implementation of co-creation and networked-learning into a regular educational program.
- The characteristics of the Innovation Space at the TU/e exactly fit the aims of the Expedition Energy Transition. Therefore, we are currently exploring the possibilities to integrate the methods and goals of the Expedition into an educational program of the Innovation Space.

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## 8. Dissemination

- We have presented our co-creation approach and given a short demonstration of LEGO serious play at the Education Innovation Day of the TU/e and at the 'kennisfestival leren in Brainport' of the Brainport region.
- During the LEGO workshop on business modeling, several teachers of the TU/e were involved as well. As most of them were enthusiastic about this new educational approach and would like to start using LEGO in their own education as well, we will organize a lunch meeting for these teachers where the do's and don'ts of using LEGO in education will be discussed. LEGO bricks will be purchased from the budget of the Expedition Energy Transition.
- To educate teachers, which will enable us to further integrate co-creation in the education of the TU/e, we will organize a train-the-trainers course on co-creation in collaboration with Claudia Depenthal of the KIC Inno Energy. This course will be financed using budget of the Expedition Energy Transition.
- The aims and outcomes of the Expedition Energy Transition will be described in a scientific paper by Boukje Huijben, Antoine van den Beemt, Anna Wiczorek and Mieke van Marion.
- The evaluation report of the Expedition Energy Transition will be shared within our own networks.

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