

Tailoring Constructive Technology Assessment for emerging technologies

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Abstract: Technology Assessment (TA) has developed into a method that puts a strong emphasis on facilitating interfaces between supply and demand of science and technology. Recently, we also see that TA becomes an integral part of science programs, for instance in nanotechnology. The basic aim of the latter is to articulate the needs, wishes and constraints, for example from users, already in the emerging stage of technological development. TA methods come in many different forms, although they are merely different versions of a limited set of 'basic approaches' adapted to specific conditions with the overall aim to improve societal embedding. The thrust of this paper lies in the development and results of a variant of CTA, addressing technological development in an early phase in order to bypass the Collingridge dilemma by developing and testing scenarios and technology options for the further development of emerging technologies.

How to support all relevant actors effectively with CTA in such a way that they are enabled to play their role in innovation processes of emerging technologies?

This is the main research question taken up in this paper. We propose a 3-step Constructive Technology Assessment (CTA) approach to take on this challenge. Assessing the effects and evaluating the approach play an important role in this work. We will apply the approach to a nanotechnology related topic, Lab-on-a-chip technology. We also work towards new methodological insights relevant for the TA community.

Keywords: Constructive Technology Assessment (CTA); methodology development; emerging technology

I. INTRODUCTION

Emerging technologies appear to be unorganised and chaotic where merely expectations and visions guide the field, rather than hard facts and prime examples 'out there'. They are therefore different from later stage technologies owing to the absence of transparent relations between actors, and the high level of uncertainty on future paths to take. Technological developments are bound to the formation of paths, meaning that in later stages of development some specific trajectories will be chosen over others.

Technology Assessment (TA) strives to improve the societal embedding of technologies, which means the extent to which the technology benefits society and becomes accepted and used without causing harms. This is a (collective) search process that should be guided in such a way that more desirable paths might be achieved, cf. Rip *et. al.* (1995:8): "That entrenchment occurs, and certain paths will be followed, is inevitable. The point is that some paths are better than others, and that these should be actively sought and shaped." In this context the so-called Collingridge dilemma (1980) is relevant: in early stages opportunities to steer are wide available, but hard to uncover, while in later stages this is reversed. CTA projects bring together content and process in order to facilitate all relevant actors to develop visions, strategies and action plans (Smits and Leyten, 1991). The assumption then is that actors are enabled to do better in their normal environment in contributing to more desirable paths. Many

different actors may play an important role in the development of technologies. Theories like Social Construction of Technology (Pinch and Bijker, 1984) and Actor Network Theory (Callon, 1986) conceive the development of technologies and their embedding in society as a co-evolutionary process. Von Hippel in this, points at the importance of users as sources of innovation (von Hippel, 1976). STS literature thus stresses the importance of the broad acceptance of technologies by different societal groups. However, in playing a role in socio-technical development, actors encounter many barriers as a lack of information on the potential, further development and consequences of a technology, problems in the discussions and negotiations with other actors and in trying to influence decision-making. Approaches like Constructive TA (Rip *et al.*, 1995; Schot, 1997), Interactive TA (Grin and van der Graaf, 1996), Real-Time TA (Guston and Sarewitz, 2002), and Interactive Learning and Action (ILA) approach (Broerse and Bunders, 2000.) are already developed to support actors and intervening in the early stages of the technological development. Still, we believe an extra effort has to be made to deal with the specific characteristics of emerging technologies in order to fulfil his role of supporting actors. We will work towards strengthening CTA especially on the issues of including scenarios development, bridging interfaces between heterogeneous actors, and organizing constructive dialogues between these heterogeneous actors. In this paper, we aim to contribute to the methodology of CTA by proposing an approach that deals with the abovementioned issues head on. This brings us to our main research questions:

How to support all relevant actors effectively with CTA in such a way that they are enabled to play their role in innovation processes of emerging technologies?

In our approach the major focus is on the visions and expectations that play a role in the development of emerging technologies. These visions and expectations can be used as a substantial basis for discussion and further shaping of these visions. At the same time we expect that developing and discussing these visions will influence the actions of actors in the further development of the technology. In order to assess whether our work actually reaches these aims, the effects of the approach should be assessed. The following sub-questions can be put forward:

How to contribute to vision development of all relevant actors?

How to facilitate a constructive discussion on the basis of visions of actors?

What and how to assess the effect of our CTA?

To answer the research questions a 3-step approach is developed, applied, and evaluated. In the approach vision development is supported by socio-technical scenarios, which are developed individually and in close interaction with the CTA analyst. Since a heterogeneous set of actors participates in the project there will be knowledge gaps and differences in information needs (Smits, 2000). Therefore, the TA exercise should focus on facilitating interfaces in such a way that effective interaction can indeed take place. Two additional aims are embedded in this CTA project; (1) actors should broaden their perspectives, and (2) socio-technical dynamics should be opened up to the actors, meaning that they understand better how technologies develop. Facilitating vision development and constructive discussion both contribute to these aims. To what extent however still has to be assessed. Impact assessment of TA projects is therefore an important issue. We will argue that impact not only relates to the content produced but also to process dimensions. The effects can be compared to the original aims to see whether they were reached.

Our approach consists of the following 3 steps: (1) providing information to the participants, (2) constructing individual scenarios, and (3) dialogue workshops.

Follow-up interviews are used as part of the data on which the effects can be assessed. This approach has recently been carried out for a nanotechnology related topic, Lab-on-a-chip technology for medical applications. Lab-on-a-chip technology till now has only a few applications on the market and is rarely used in practice. This highlights the emerging stage this technology field is in, which makes it a good case to test our approach.

The outline of this paper looks as follows. First, we will take the reader through an introduction on TA and CTA followed by a description of the basic design characteristics of the proposed CTA approach; the 3-step approach. Also, a research design to assess the effects is introduced. The next section reports on the results, effects, and evaluation of the CTA project for the Dutch Lab-on-a-chip community. We end up with drawing conclusions and giving methodological recommendations.

II. INTRODUCTION TO TECHNOLOGY ASSESSMENT

To give the reader a flavour of the development and nature of TA, we will start this section with a short history. We then turn to the characteristics of Constructive TA in more detail. This gives ample basis for the next section; the development of the 3-step approach specifically addresses emerging technologies via a tailored version of CTA.

Short history of TA

-- left out due to limitations in number of words --

Characteristics of CTA

Here, we discuss which developments led to the basic characteristics of CTA. First, CTA strives after *including all relevant actors early in the development process*. Second, *facilitates interfaces* between supply and demand of science and technology, which implies a platform where actors can interact in a constructive way. Third, CTA practices are also *informed by studies of technology dynamics*. Fourth, CTA exercises have a clear *process orientation*. -- Highly condensed version --

III. TAILORING CTA AND EFFECT ASSESSMENT

The characteristics of CTA together with the aims of our work as discussed in the introduction constitutes the input to describe the 3-step CTA approach that is central in this paper. The case on which the approach is applied and of which examples are given in the text below is presented in Box 1. By suggesting different designs of the same approach, effects can be assessed in more details, which can lead to new methodological insights. To evaluate the approach, follow-up interviews are suggested as a part of the data to assess the effects. The last part is devoted to discussing a research design to assess the effects of the CTA study.

Box 1: the case of Lab-on-a-chip technology in the Netherlands

Lab-on-a-chip technology has its roots in microtechnology fabrication technologies, which enabled the fabrication of the first fluidic chips at the end of the 1980s. A fluidic chip is a piece of material in which small fluid channels are made of which the design enables various miniaturised (bio)chemical analysis.

-- Shortened version --

A 3-step CTA approach

We now present our 3-step approach that takes into account the abovementioned characteristics of CTA and is adapted to the specific characteristics of emerging technologies. As mentioned before, we will work towards strengthening CTA especially on the issues of including scenarios development, bridging interfaces between heterogeneous actors, and organizing constructive dialogues between these heterogeneous actors. The 3 step approach consists of: (1) providing information to the participants, (2) constructing individual scenarios, and (3) dialogue workshops.

Emerging technological fields are dominated by expectations and visions of options and opportunities regarding what the technology could be, rather than many innovations and applications that have already proven their value as is the case for established technologies. Further, there is high uncertainty about future paths and a lack of transparent relations between actors. It is unclear who is doing and should be doing what to make the technology successful. The demand side also is largely unaware of the possibilities. What does this mean for CTA exercises? First of all, the participants should be informed about the past developments of the field. This should be based on an in depth case study of initial structures and roles (e.g., v. Merkerk & Robinson, forthcoming). These initial roles and structures can give information of irreversibilities that already arose, but are difficult to put the finger on for the actors in the field. This is also part of the first step in the CTA approach: *providing information*. This provision of information has two reasons; (1) to decrease the asymmetry that is naturally present in any emerging field, and (2) to provide information that is not yet available, but is needed for the participants to develop their visions and build their arguments upon. The latter is taken up in all steps. In the first and second step individually, the participants are stimulated to articulate their own view on the future, and in the third step the discussions and outcomes of interactive meetings provide relevant information for the participants.

Second, since the CTA analyst (almost) only has expectations and visions to work with in the case of emerging technologies, working with scenarios is a promising addition to the CTA methodology. Since the emphasis is also on broadening the perspectives of the participants, *socio-technical scenarios* – highlighting a broad variety of aspects (technological, economic, political, and socio-cultural) – are used in this approach. In articulating their prospective view on the field, the participants were carefully guided. The scenarios are developed individually in face-to-face interviews to elicit the personal expectations and visions of the field. The set of participants not only comprised of scientists and businesses, but also of potential users, policy makers, investors, and in this limited case on medical applications, insurance companies. The invitation of participants was done cumulative, which means that invitations were sent out as the interviews and other interactions proceeded. The CTA analyst gets to know the field better as he is visiting participants for the individual scenario interviews. This enables the project to build extensively on the knowledge from the field. For example, participants expressed opportunities for biotechnology companies to use Lab-on-a-chip technology to develop medical applications. Therefore, the scope was enlarged, the companies were invited, and so the field was served. This example highlights the process character. Analysis of the scenarios gives insight in the initial roles of the various actors and provides valuable input to the next step where the participants meet.

A dialogue workshop was the third step – Shortened version -- A workshop consists of three rounds, starting with two rounds focused on the scenarios followed by a brainstorm in which the participants are asked to formulate technology options, which are combinations of applications for specific markets or practices. Convergence is aimed for by scoring the preferred technology options (on feasibility and desirability) of the participants with a prioritization matrix. This last, converging round gave the participants an overview of which applications

were held most desirable and feasible by the group present at that workshop. This design does not guarantee that convergence is reached, but then the participants become knowledgeable about these different perspectives and can take them into account in the development of their plans. – Shortened version -- Two months after the workshops, telephone interviews were held with all fifty participants. Important here is to verify whether the effects expressed by the participants can be related to the CTA project or something that happened without a relation to the intervention.

Different workshops for methodology development

Looking back at the characteristics of CTA, for emerging technologies we have to be aware that incorporating all relevant actors might not be the most constructive approach. Until now, this remains a research question that can be formulated as follows: when dealing with actor compositions in workshops for emerging technologies, will 'incorporating all relevant actors' yield a more constructive interaction and outcome compared to a more heterogeneous actor composition? Constructive here means a positive interaction in the sense that the participants are stimulated in acquiring the information they need or think they need. Also the point of facilitating interfaces is relevant here. Interfaces can be typified in a variety of ways, being in a very detailed or more general way. One of the questions here is whether it is valuable for the exercise to pay attention to every possible interface (e.g., between different science communities) or to group the actors in a more collective manner (e.g., scientists and the health care community) and design specific interfaces. To investigate this question, we organised two workshops that include all relevant actors as well as two workshops that focus on a specific set of actors. In doing so we make a distinction between insiders and outsiders (Garud and Ahlstrom, 1997), where insiders work towards the realisation of the technology and are committed to its success (like science and business), and outsiders are selectors in the sense of having multiple options to solve their problem of which the technology under discussion is just one (like end-users and ministries).

We also vary another parameter. The start of a discussion (in small settings) can influence the course of a discussion and the interaction, because interactions built on each other, can result in a kind of 'conversational path dependency'. Since the interactions during a workshop influence the outcome, it is valuable to study whether there is an effect that should be accounted for in CTA methods. We make the following distinction: starting a discussion based on the scoring of controversial issues (that come out of the analysis of the socio-technical scenarios), or on the presentation of an individual scenario by a participant. – Shortened version -- Figure 1 illustrates the two variations in set-up.

| | | Actor composition | |
|---------------------|------------------------------|-------------------|--------------|
| | | <i>Insiders</i> | <i>Mixed</i> |
| Start of discussion | <i>Scenario presentation</i> | 1 | 2 |
| | <i>Issue selection</i> | 3 | 4 |

Figure 1: the resulting four different set-ups of the dialogue workshops.

Research design to assess the effects

Assessing the effects of TA studies has (and will always be) a difficult issue. Reasons are that; there are more effects than you can see and observe from the outside, because you work with effects on (collectives of) human beings. Moreover, effects can be unconscious or long term. Also, innovation processes are very context dependent and so is TA. This context dependency implies that case-by-case decisions have to be made on the expected and wanted effects. The way to assess these effects should be clear from the start of a project, because a part of these effects will appear during the process and should be monitored accordingly. Besides these remarks, there are always two questions to start with: what and how to assess? Let's start with the *'what'-question* in light of a distinction made by (Bhola, 2000) on impact evaluation. First, for every intervention – as for this CTA study – there are intended outcomes that are incorporated in the design (impact by design). Second, there can be effects that occur after the intervention interacts with other interventions (impact by interaction). For example, participants meet each other again at another event, which strengthens their ideas on which they follow-up on each other. Thirdly, effects can emerge after the previous happens and in addition links are being made between wider historical and cultural processes (impact by emergence). In the next section, the thrust of the discussion of effects will lie on the intended effects assessed in a way to be discussed shortly. Nevertheless, when effects are observed that fall outside the intended effects, the division from Bhola (between intended and two types of non intended outcomes) gives us an anchor point to discuss the data and results in more depth. Returning to 'what' to assess, we aim to show what effects can be expected in general (when using the 3-step approach) and to show and explain the differences – when they exist – between the four different workshops. Further, a natural and valuable distinction can be made between effects in terms of content and process; content being every aspect of information that is input to the process or generated in the process, while the process dimension deals with the facilitation and the actual structure of the CTA study.

During the CTA project, participants acquire and use the information that is provided to them (*content* dimension). This can either be acquired in relation with

the CTA analyst, as we see in all three steps of this project, or acquired in interaction with other participants in the dialogue workshop (step 3), and even in follow-up activities initiated by the participants themselves. The effects of this knowledge take up and use can be assessed on three dimensions, being 'raising knowledge', 'forming attitudes/opinions', and 'initialising action' (Decker and Ladikas, 2004). These three types of effects are dimensions of uptake and use. But there is more at stake when assessing the content dimension of the effects of TA. As highlighted before, this CTA project aims to broaden perspectives and open up socio-technical dynamics. A wide variety of aspect – technical, economic, political, and socio-cultural – are important in the eventual use and diffusion of the technology in a socially sound manner (improve social embedment) and to reach the aims, these aspects are therefore dealt with in the different step of the approach. Criteria for quality monitoring of CTA have been proposed exactly in light of this issue of including a broad range of aspects (Schot and Rip, 1997; Schot, 2001). Inspired by this work, this study strives to improve anticipation, reflection, and learning and thus also takes these types of effects into account. *Anticipation* of the future deals with whether participants take longer term effects into account. Relevant trends and expected changes are dealt with in the here and now in assessing the opportunities for the technology under discussion. *Reflection* is an expression of insights that were gained by looking at one's own perception from another angle or viewpoint. It is therefore a reassessment of perceptions held when participants are confronted with other aspects. *Learning* can be either more factual (new or adapted insights) or more towards the understanding of the underlying dynamics of technological development.

-- Shortened version --

The *process* dimension is dependent on context as well as on the institutional setting. We see context as the actual status of the technological field or the problem situation. The institutional setting deals with the institutional boundary conditions from which the TA is organised. Both aspects influence the types and level of effects that can be expected from TA exercises. The fact that we deal with emerging technologies in this study is the important part of the context for this CTA study and has been taken up in the 3-step approach as discussed above. The institutional setting can be discussed and assessed at length, but we want to focus on three relevant questions: did we achieve to get the 'right' user involvement, did we achieve to provide effective support to participate in the discussion, and did we achieve to facilitate the interface between insiders and outsiders?

The *'how'-question* is directly related to the design of the data collection. The major sources of data are the socio-technical scenarios, transcripts of the workshops, and to assess the effects on the participants when they return to their 'normal' working environment, follow-up interviews are conducted by telephone two months after the workshops. The interviews focus on whether the participants initiated new actions or interactions in their work that are directly related to the CTA exercise. Also, we wanted to know whether the total group of participants was influenced, in the sense that they now have a clearer view on where the technology might be heading to and where opportunities lie for desired applications. In other words, whether they developed a shared frame of reference. In addition, questions were asked whether the individual scenario had changed due to the workshop, and if they experienced any changes in the way they interact in their work (e.g., when talking to colleagues or assessing opportunities for collaboration).

To summarize, the research design to assess the effects is split into a content and a process dimension. The content dimension is filled in by two sets of effect indicators; (1) 'raising knowledge', 'forming attitudes/opinions', and 'initialising action', and (2) anticipation, reflection, and learning. The process dimension focussed on three questions as mentioned above.

IV. RESULTS AND EFFECTS OF TAILORED CTA IN PRACTICE

In this section, the research design to evaluate the effects of the CTA approach, as developed above, will be applied to a CTA project for the Dutch Lab-on-a-chip community. We start by presenting the results in knowledge take up and use. Then we deal with effects in terms of anticipation, reflection, and learning. Differences owing to differences in workshop design are the next content issue, followed by an evaluation of the process dimension.

Knowledge take up and use: raising knowledge, forming of attitudes/opinions, and initialising action

Assessing the results along the lines of the three dimensions of Decker and Ladikas (2004) shows the following results. A vast majority of the participants (about 85%) indicated in the follow-up interviews that their scenario changed at least on details. This shows that their *knowledge has been raised*. Further, there is no observable difference between the different workshops.

The follow-up interviews also revealed whether the participants take into account more actors/aspects owing to their participation to the project. A positive answer indicates that they look differently towards the field and the players/variety of aspects than before, showing a change in attitudes and opinions. For roughly 75% this was the case and thus we see that *attitudes and opinions were formed and shaped*. An exception is the workshop with only insiders and scenario presentation (No. 1 in Figure 1). This workshop showed more contestation and opposition probably hampering a possibly more constructive dialogue. Looking at how the interactions in this specific situation developed, one can draw a link to the fact that scenario presentation was used in this instance. The start of the discussion is focussed on a single person rather than an issue (as with issue selection). Therefore, when the scenario is presented, a situation can develop where the presenter (maybe backed up by others) defends his view, which can continue for some length of time. A more constructive situation would be to have an open and equal discussion among the participants.

When we turn our attention to whether the project *initialised action* from or between participants, there is almost no effect. There were some facts like a few arranged appointments with other participants, talks about small initiatives, or further elaboration of a particular case inside the organisation. There were no actions initialised between insiders and outsiders. In addition, the participants indicated that these effects could often not be fully related to the work done in the project, but stimulated by the project or interacting with other activities where they met the same people again. This links up with the second distinction from Bhola (2000) (impact by interaction), which we can understand by stating that multiple stimuli for action are likely to be more successful. Further, data from the follow-up interviews indicates that initialising action can be a type of effect that needs more time. The intention may be there (also for insider-outsider initiatives), but action is postponed, for example because current projects are running and changes are only possible when new projects are initiated. So, when 'new understandings about how the world works' (forming attitudes) are gained, for example that broader actors and aspects have to be taken into account, a certain incubation time has to be taken into account when assessing the effects, which is the third type of impact as distinguished by Bhola (2000) (impact by emergence).

Anticipation, reflection, and learning

These three types of effects were assessed based on data from the transcriptions of the workshops as well as the data gathered from the follow-up interviews. From the transcripts, it is difficult to see whether there are instances of anticipation, reflection, and learning. Reasons are that there is only one person talking at the time, when the others think and listen (which can have effects as

well). Also, interpretation of these instances is left to the CTA analyst and thus do not need to be correct. This does not mean that the effects are not there.

The follow-up interviews show more anchor points for assessing these types of effects. An indication for anticipation can be found if participants indicate changes in their scenarios by taking into account longer-term developments. Reflection can be elicited from the way the answers were given; with an indication that they revised their standpoints. Still, almost no effects were found when looking to anticipation and reflection in this way. When we turn our attention to learning there is a second order effect following from the point that most participants formed and shaped their attitudes and opinions, i.e. now take into account more actors and aspects'. The participants were asked whether they expected to change their reaction to a request for collaboration. About half of the participants expected to do so. They for example intended to include a wider range of actors than they were used to.

Differences owing to variation in workshop design

Taking the variation in *actor composition* (mixed versus an insider workshop), Garud and Ahlstrom (1997) teach us that insiders use narrow evaluation frames to assess a technology, while outsiders use broad evaluation frames. Translating this to a small setting where either insiders are present or a mix of insiders and outsiders we get the following. One can expect that insiders focus on technology based reasoning, while a mixed group focuses more on selecting technologies for specific purposes. The transcriptions of the workshops show a discourse that links up with this distinction. In the two insider workshops technology as such is an issue, while in the mixed workshops technology is taken as given. The insider workshops elaborate on technological aspects and can stay longer with technological topics. The mixed workshops take more general topics to discuss for longer periods of time, reflecting the broad evaluation frames held by outsiders. This is corroborated by data from the follow-up interviews, which shows that participants from the insider workshops more often indicated the changes in their scenarios of a technological kind. -- Shortened version --

When we look at the issue of '*conversational path dependency*', there are no clear indications that the *start of the discussion* leads to a dominant discussion. Discussions can continue on the same subject for quite a while, but this happens when the discussion is initiated with scenario presentation as well as issue selection. There are indications though that issue selection gives a more constructive dialogue. Scenario presentation is more likely to provoke opposition among the participants. With issue selection, the participants decide where they want to talk about as a group. The discussion topic is therefore easy to accept and not connected to a single person.

Process evaluation

The process dimension focussed on three questions: did we achieve to get the 'right' user involvement, did we achieve to provide effective support to participate in the discussion, and did we achieve to facilitate the interface between insiders and outsiders? A challenging part in terms of the process dimension (although it is only relevant for the participants in the two mixed workshops) is to get *all relevant actors* involved in the project. The design of the project should then enable all participants to contribute in an effective way (of special attention in the mixed workshops). The involved actors in the mixed workshops originated from science, business (SMEs and large firms), end-use (GPs and hospital care), ministries, financial institutions, and health care insurers. In constructing heterogeneous groups there is an issue on how far you can go, because there is a natural tension on group size and enabling a constructive dialogue. When the group grows, not only discussions become more difficult simply due to the size of the group, but also differences in background of the participants can become too manifold. -- Shortened version --

On *providing effective support* to participate in the discussion, the first two steps in the project (providing information and constructing individual socio-technical scenarios) proved effective in terms of their aim, to prepare the actors for a broad discussion on a wide variety of aspects in the dialogue workshops. Some participants indicated this by mentioning that they were surprised and satisfied by their scenario, because they were able to come up with a coherent story dealing with a broad range of aspects. Further, participants often referred to their scenario (either explicit or implicit) during the workshop, showing that, at least to some extent, the scenarios functioned as a basis for the discussion.

We believe that we achieved to *facilitate the interface* between insiders and outsiders as both types of actors were present and contributed to the discussion. The participants also indicated that they were pleased with how the project was organised. Further, they indicated that they wanted follow-up activities to continue the discussions in one way or the other.

In summary, the major findings are the CTA project for the Dutch Lab-on-a-chip community had a considerable effect on raising knowledge and forming attitudes/opinions. The effect of initialising action had to be put in a larger context to see possible longer-term or deviated effects. Further, assessing effects in terms of anticipation and reflection seems problematic, while learning is more doable and the effect was also shown. Also, the mixed workshops take technology as given, while in the insider workshop technology is an issue. The three process evaluation questions could be answered positively.

V. DISCUSSION, CONCLUSIONS AND IMPLICATIONS

In the previous section, the effects were discussed and assessed in light of the research design to assess the effects as discussed in section III. This section will first put forward and answer the research questions as formulated in the introduction. The conclusions will also focus on whether the aims in terms of broadening the perspectives of actors and open up socio-technical dynamics to them were reached. We will then point out what the 3 step CTA approaches has to offer compared to other CTA approaches. Last, we will assess the value of this approach from a methodological perspective.

The main research question was: *how to support all relevant actors effectively with CTA in such a way that they are enabled to play their role in innovation processes of emerging technologies?* We will first answer the sub-questions individually.

How to contribute to vision development of all relevant actors? The formulation of socio-technical scenarios made the personal visions explicit. The dialogue workshop then gave the participants the opportunity to test their visions resulting in adjustments to the scenarios as revealed by the follow-up interviews. Also, the various aspects as put forward in the scenarios and workshops were meant to be broad (technological, economic, political, and socio-cultural). Further, a considerable portion of the participants expressed that they now take into account more aspects and actors in their work. This can have an influence on changed strategies and on assessing and establishing collaborations. Although, we should not forget that some actors are already knowledgeable on this issue in the sense that they work, for example, with sounding boards to evaluate applications in their own organisation. This does not mean that they can't learn and broaden their perspectives even further. Nevertheless, some of these people indicated during the follow-up interview that the project didn't broaden their perspectives, because they already were familiar with thinking about a broad range of aspects.

How to facilitate a constructive discussion on the basis of visions of actors? A constructive discussion can initiate learning effects as seen in section 4. We showed that opening up socio-technical dynamics (the way technologies develop

in society becomes clearer) was achieved with a considerable part of the participants. The fact that learning took place on how to organise collaboration is an indicator for this. There is more to tell on this issue. The previous section considered learning effects and showed that the mixed workshops had a larger effect on changes in interactions, especially on how the participants perceived novel collaborations. Further, in a mixed workshop insiders and outsiders can react directly to each other. Does a mixed workshop therefore give more opportunities for learning and reflection? The few instances of reflection that could be found in the transcriptions of the workshops hint this way. Although this is a question lacking a clear answer, the authors believe this is indeed the case.

What and how to assess the effect of our CTA approach? Section III gave the answer to this question, but did the research design to assess the effects proof to capture the effects? The distinction between content and process is inherent to the characteristics of CTA (see section II) and is therefore a valuable division for evaluation. Both dimensions have their own focus point. They were therefore filled in differently and they shined their light on different aspects of possible effects. Nevertheless, there will always be effects that could not be surfaced.

We now return to the main research question. The 3-step approach proved to fulfil this role as the effects of the CTA project show. Broadening perspectives and open up socio-technical dynamics in principle enables actors to do better in their normal working environment, and eventually contribute towards more desirable paths. We therefore conclude that the 3-step approach does enable all relevant actors to play their role in innovation processes of emerging technologies. But, for this to happen in practice, action is needed and we saw that on the issue of initialising action, the CTA approach was less successful. What can we learn from this result? We already discussed that in light of this issue often more interactions are needed, learning points have to be digested, and/or situations have to change before new actions are taken. Would it then be better when the participants meet more often (possibly in different settings and composition) within the same project? Taking the discussion here into account the answer is yes. However this would require a more intensive project and the CTA analyst should take into account that the process itself becomes more explicitly a point for discussion (Reuzel *et al.*, 2006). Also, the time-spending of the participants will increase, which means that recruitment becomes much more difficult and one has to consider continuation and duration more seriously. Nevertheless, multiple meetings do have the advantage that one has the opportunity to work towards effects more in terms of initialising action.

This paper claims that the 3 step CTA approach as put forward in this paper has an added value compared to other CTA(-like) approaches when it comes to emerging technologies. But how far did we advance on this issue after applying and evaluating a specific case? First of all, the evaluation was positive on the aims (broadening perspectives and open up socio-technical dynamics) and the main research question (with the remark on initialising action). This gives us reason to conclude that the 3-step CTA approach fits for emerging technologies. Second, if the focus of a CTA activity is on generating technological inspired applications, the goal is only reached when the CTA analyst chooses an actor composition consisting of insiders. When a project consists of multiple meetings, this is a point for consideration; one of the meetings can then be filled in this way. Third, we saw that it is valuable to discuss scenarios in a group, but not by having individuals present their scenario. An exception to this is when one wants to focus on controversies, because as we have seen in section 4, scenario presentation can lead more easily to contestation, which is valuable for highlighting and discussing controversies. Last a related item to the previous; we saw that issue selection has a higher chance to initiate constructive meetings since it steers away from contestation. As a consequence this could also have an effect on improved broadening of perspectives by the actors.

What methodological take home messages can be formulated? First, CTA for emerging technological fields with a mixed composition of actors is seen as valuable by the participants. After the mixed as well as the insider workshops the participants expressed the relevance of the project in the closing discussion as well as in an evaluation query of the workshop. Second, we want to highlight that having a research design to assess the effects should be a requirement for all TA projects from the start. What we call an effect is a normative issue. Beforehand it should be clear what the participants conceive as the strived after effects, which is especially true for TA focussing strongly on process characteristics as is the case for CTA. Follow-up interviews proved a well suited method for generating data for assessing the effects. When data from the different data sources corroborate, stronger arguments can be made. The research design for assessing the effects should take this into account.

To wind up, as can be seen from the answer on the main research question, the proposed 3-step CTA approach is able to bypass the Collingridge dilemma to some extent. Nevertheless, we do believe that more work should be done on variations of the approach, following the lines expressed here to work more towards initialising action and by this, have more effect on the daily practices of all relevant actors. Only through the actions and interactions of the people in the field, CTA can have its real contribution to improving societal embedding of emerging technologies.

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