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Double stimulation for collaborative transformation of agricultural systems: The role of models for building agency

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ABSTRACT

This article describes an investigation into how to build agency among growers so they take the lead in transforming their own activity of managing whiteflies. The study shows how the principle of Transformative Agency by Double Stimulation (TADS) was applied in a formative intervention based on the Change Laboratory method for developing pest management among greenhouse vegetable producers in Finnish Ostrobothnia. The data comprise audio recorded sessions, documentary data and observations produced and collected during the intervention. The results show how the collective construction of a continuous series of models during the intervention played an important role in learning, prompting TADS among the participants and working as a communication tool for the practitioners' different conceptualizations of the problem and possible solutions. The models allowed materializing and expanding the way the participants understood the temporal, functional and spatial aspects of the problem. In the study, TADS took place through conflict of stimuli and motives, first stimulus, auxiliary breaking-away second stimulus, and actions that were initiated to improve the management of the problem at hand. In conclusion, the principle of double stimulation was useful to produce transformative agency, helping transform the activity of pest management among the horticultural producers.

1. Introduction

Radical transformation of human activities requires transformative agency (Haapasaari et al., 2014; Lopes et al., 2018; Sannino et al., 2016; Vänninen et al., 2015; Virkkunen, 2006) – the capacity to form and implement intentions that go beyond the accepted routines and given conditions of the work activity in which the subjects are involved, to transform that work activity qualitatively (Engeström & Sannino, 2013) The purposeful actions by human agents to support the redirection of ongoing change can be accelerated by interventions based on the principle of transformative agency by double stimulation (TADS) (Engeström, 2007; Engeström et al., 2014).

In a previous study, Vänninen et al. (2015) showed that transformative agency can be promoted using a method termed Change Laboratory (CL), which applies a double stimulation (DS) principle. The authors showed that the formation of this type of agency takes place through six forms of action expressed during an intervention aiming at change. Despite the advancements, little is known about

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the dynamics of interaction in which DS leads to transformative agency (Haapasaari & Kerosuo, 2015). Our research aim was therefore to investigate, by using Cultural-Historical Activity Theory, how agency among a group of actors with a shared problem could be supported so that they could take the lead to transform their own activity. In this context, we investigated how the dynamics of interaction involving DS as a psychological tool resulted in transformative agency. Our study applies Cultural-Historical Activity Theory to evaluate whether and how the principle of DS, as a psychological tool, can be used for building farmers' transformative agency so that they transform their own activity. The principle of DS, proposed by Vygotsky (1931/1994, cited by Sannino, 2015) means the human ability to willfully transform their behavior and the surrounding world employing auxiliary means (Sannino, 2015; Sannino & Laitinen, 2015). In this article we used a model of DS developed by Sannino (2015) for will formation by in-depth reanalysis of the concept that was initially coined by Vygotsky (1931/1994). Sannino (2011) defines it as "the mechanism with which human beings can intentionally break out from a conflicting situation and change their circumstances and solve difficult problems". It is the generative mechanism of willed quest for change (Engeström, 2007). The case where the unfolding of transformative agency by DS was studied involved a multi-actor group consisting of actors representing greenhouse growers, advisors, packing house CEOs and a pest management researcher in a region where whiteflies constitute a collective problem for about 145 greenhouse firms. The learning challenge for the producers and other actors was to improve the integrated management of a whitefly (*Trialeurodes vaporariorum*) problem that was affecting a large number of horticultural greenhouse entrepreneurs. Here, the principle of DS was applied for forming a new understanding of the idea of the activity of whitefly management and a new perspective on its future development. Change Laboratory and DS are presented as a method for supporting co-innovation and understanding on how it is affected by the process of interaction among participants representing different roles.

In order to grasp the process of the formation of TADS, we formulated the following research questions: 1. How can the principle of TADS, by collectively creating and using models of the whitefly problem, be applied during a formative intervention aimed at solving a collective problem that involves a large number of greenhouse growers and other actors? 2. What were the phases of such intervention based on TADS, i.e. how did the process unfold and how did it contribute to transformative agency of the actors participating in the CL? 3. Did the principle of TADS lead to building transformative actions that resulted in better whitefly management? To answer these questions, we analyzed discursive data from the intervention conducted among greenhouse growers in Finnish Ostrobothnia.

In this article, we start by outlining the learning challenge which motivated the collective will-formation among participants of the intervention to resolve the described pest management problem. Thereafter, we present the theoretical framework for depicting the process of TADS as a means to support the emergence of collective will. Subsequently, we move to presenting data collection, methods of analysis, and results. Lastly, we answer the research questions presented above and discuss the extent to which the principle of TADS took place and how it contributed to the unfolding of transformative agency among growers during the intervention process.

2. The learning challenge represented by whiteflies

The Ostrobothnian greenhouse cluster on the West coast of Finland consists of about 145 enterprises located in close proximity to each other, facilitating dispersal of both established and potentially new pests among greenhouses (Ovčarenko et al., 2014). Since 1995, there has been a rapid expansion of year-round production in the area based on heating and lamp-based lighting. This improved revenues of greenhouse firms through exploitation of a new market position (winter months) in the competitive market of greenhouse vegetables. Nevertheless, year-round greenhouses sustain pest problems because there is no cold period to kill non-indigenous pests and because they produce a higher number of pest generations per year due to the long or successive cropping cycles. Furthermore, some natural enemies, the principal means of managing the pests, perform sub-optimally in the wintertime (Vänninen et al., 2010). The seasonal production concept includes a production break in wintertime that efficiently kills all non-indigenous pests due to their lack of cold tolerance.

Due to the risks described above, the interdependency of greenhouse firms through shared pests needs to be taken better into account in the plant protection strategies of producers. This was the context for the demand for the formative intervention conducted in this study. Participants in the intervention were the producers and other actors whose role is linked with improving pest management in the area. The prevalent whitefly pest, *T. vaporariorum*, was the model organism used to develop collective pest management by producers. This species serves as a proxy for developing management options for additional non-indigenous species that are still absent in the area. In order to proceed towards alleviating the problem represented by whiteflies, the growers must first understand how the problem began and was sustained and what their own role was in sustaining it. To achieve such understanding, the problem was modeled first to visualize it for collective scrutiny and analysis. This modeling process, a crucial part of addressing the learning challenge, produced the auxiliary means mentioned above in the context of the principle of DS that is designed to result in transformative agency. We now proceed to present the theoretical basis of TADS in more detail.

3. Transformative agency through double stimulation: theory

The word "double" in the principle of DS refers to two types of stimuli that interact to induce agency. The first stimulus is a challenging situation, e.g. the problematic activity itself. It manifests itself as problems, disturbances, ruptures and contradictions that convey to the practitioners that there is a need to change their activity in one way or another. The second stimulus consists usually of instrumental artifacts (such as models produced during the intervention described in this article) given to or constructed by the subject to serve as instruments that help to break away from the problematic situation (Sannino, 2015). In other words, such instrumental artifacts, or auxiliary stimuli, form the basis of the process of building transformative agency.

According to Engeström and Sannino (2013), the breaking away from the original problematic situation using the second stimulus

proceeds in two steps: 1) an artifact, or an auxiliary stimulus, is chosen or created and loaded with meaning and sense, 2) an action is laid out using the artifact as a mediator sign that allows the subject to control actions and understand the problem or the initial circumstances.

Sannino's psychological model of DS is divided into two parts (Fig. 1). Apparatus 1 consists of the formation of a decision to act in a certain way by means of the introduction of an auxiliary motive that enters in conflict with an initially existing motive. The decision is formed through four successive phases: 1) conflict of stimuli (demands or expectations that pull in opposite directions, such as the whitefly problem that needs to be solved but there are different expectations as to who is responsible for solving it); 2) conflict of motives (activated by conflict of stimuli, leaving the subject at the mercy of motives); 3) conversion of one stimulus into an auxiliary motive, or a second stimulus; it can be formulated by the subject, or it is given to the subject by someone else; and 4) closure (Fig. 1). In phase 1, the clash between stimuli triggers the formation of Apparatus 1. A good example of an application of DS for the development of work was is given by Sannino (2020a, 2020b) in a Change Laboratory conducted with workers from a housing unit for formerly homeless young people. In the study, the author defines conflict of motives as "the core conflict of motives in the unit between the old culture of control which meant that both employees and residents 'followed the rules to the letter' and the emerging culture of 'trust,' 'flexibility' and 'discretion.'" (Sannino, 2020b, p. 14). The problem could not be solved using the old methods or framework. Conflict of stimuli and of motives is opened up also in Engeström et al. (2020).

In phase 2, the conflict of stimuli activates motives, involves them in the conflict of stimuli and turns the conflict of stimuli into a conflict of motives. The conflict between the motives often occurs well before the concrete situation is born in which it becomes necessary to act (Engeström & Sannino, 2013).

The motives play a key role in the formation of voluntary actions, i.e. choosing among alternatives as to how to act in a given situation. Practitioners of the activity realize that the problems cannot be explained by using the old knowledge or framework. Instead, new knowledge and understanding of the situation are needed. This realization generates an internal conflict and the need and motivation to learn (Sannino, 2011) or to appropriate the new (Lund & Rasmussen, 2008). In phase 3, one stimulus is selected and converted into an auxiliary motive. Having engaged in the conflict of motives with the identification of an auxiliary motive, one becomes more solidly grounded in the perception of what must be done in a certain situation (Sannino & Laitinen, 2015). Thus, auxiliary stimuli are needed to facilitate breaking away from the problematic or conflicting situation and to help overcome "the pull of the past" (Engeström, 2015; Sannino, 2015). To serve as the second stimulus, auxiliary artifacts must be turned into productive instruments of inquiry capable of solving their users' conflicts and to facilitate expansive thinking towards the new (Engeström, 2015).

Phase 4a in the apparatus of decision-making represents a critical point in the formation of voluntary action. In this phase, the real or actual conflict of stimuli takes place. It starts when the neutral, auxiliary stimulus appears. In the classical waiting experiment described by Vygotsky (Rieber & Carton, 1987), a person in the room has been told to wait for the experimenter who never shows up. The person faces a conflict of motives: to stay in the room as told although nobody comes, or to leave. The person decides to leave when the clock – the neutral stimulus – on the room wall strikes, say, 2:30. When the direct, neutral stimulus occurs, the person is confronted with "a signal (the clock striking 2:30) and a connection with it (decision to act in a certain way)". The closure mechanism of Phase 4b

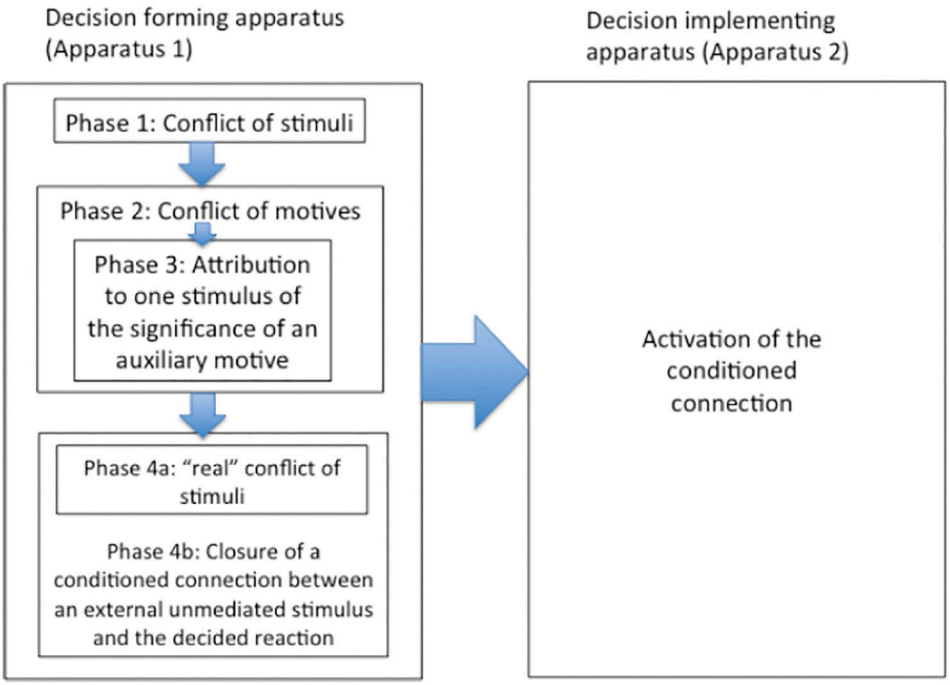

Fig. 1. Model of double stimulation for will formation (Sannino, 2015).

is the "closure of the connection between the given stimulus and the reaction". From this follows implementation, i.e. the execution of an action according to the instructions: "I leave the room at the signal of the clock hand turning to a certain time" (Apparatus 2 in Fig. 1).

In light of the functional model described in Fig. 1 and activity theory based formative interventions, TA encompasses willful collective engagement in overcoming critical conflicts with the help of mediating cultural artifacts characterized as a second stimulus. The three components of TA – the situation of conflicting motives; construction of an auxiliary stimulus; and practical action that can transform the situation – are generally present together in successive steps that form a longitudinal chain of auxiliary stimuli. This makes TA a process that involves progressive, expansive understanding of the problematic situation and giving new meanings to it, rather than any decisive moment of realization of how to solve the conflicts in the activity. The element of expansion associated with the longitudinal chain of auxiliary stimuli is regarded as a fourth element of TA. In formative interventions that bring together practitioners of a given activity system or systems, TA thus becomes a sustained, collective effort (Engeström & Sannino, 2013).

Recently, the process of promoting agency through DS has been theorized as Transformative Agency by Double Stimulation (TADS) (Engeström et al., 2020). TADS may be prompted by interventions based on specially planned forms and methods termed formative interventions (Morselli & Sannino, 2021; Sannino, 2020b; Virkkunen & Newnham, 2013) Formative interventions involve participating actors in successive sessions in an intensive collaboration, inquiring about the developmental challenges of and possibilities for the collaborators' activity to transform it qualitatively (Virkkunen & Newnham, 2013). In this study, we applied a formative intervention method, the Change Laboratory, which encompasses analyzing, modeling and transforming an activity, and it can be used to facilitate both deep and intensive transformations or continual incremental improvements. The method is based on the principle of DS (Engeström, 2007; Virkkunen & Newnham, 2013), which mobilizes the realization of a first stimulus as well as of auxiliary means (second stimulus) – signs and tools, which can be used to address the problem. In the CL, the first stimulus is constructed with the help of so-termed mirror data that are perceptual materials conveying limitations and shortcomings in the activity. Another important tool is the visualization of the time dimension (past, present, future) of the activity as a developing system.

4. Methodology: data collection and method

4.1. The data from the intervention

In order to deal with the growing problem described in Section 2, growers demanded an intervention from the first author of this

Table 1
Change Laboratory sessions and their contents in Ostrobothnia.

Session (no. of participants)	Contents (general aim)	Working methods	Output
I (11)	What actually is the problem with the whitefly? How does the problem manifest?	Presenting and discussing the first stimulus (mirror data) (photographs, graphs, audio-excerpts of interviews)	Initial sketch of the second stimulus.
II (13)	What is causing the whitefly problem, what are its inner systemic relations and its historical origins?	Historical story of the problem. Discussing the components of the second stimulus.	Time –line of problem development. Notes for further development of the second stimulus.
Two year-round growers. Advisor	Feedback for the systemic pest model (second stimulus) under development.	Discussion	Notes for further development of the second stimulus
III (9)	Design and model solutions to the problem.	Group discussion around the finalized second stimulus	Initial sketch of new model of activity (solution to the problem). An idea to construct a website for data sharing between growers.
IV (6)	What needs to be done to solve the problem? Examining the new model of activity. Deviation from this plan.	Group discussion. Models of new activity and of developmental paths. A matrix of redesigning elements of activity system. Reappearance of conflict of motives.	Resolving the conflict of motives. Decision to have a break in the process, to interview seasonal growers, and plan the next session in detail.
Two year-round growers. Two facilitators.	Ex tempore meeting during a horticultural exhibition: Planning the strategy for building the next session.	Small-group discussion.	Ideas for planning the next session.
Two year-round growers. Two facilitators	Planning the next session	Group discussion in one of the firms.	A plan for the next session.
V (11)	Planning the implementation of the new model of activity.	Group discussion. Model of the new activity. Prototype of website for information sharing.	A plan for monitoring trial.
Between sessions V and IV	Implementation of the new model of activity (whitefly monitoring using a common method to get comparable results)	Results from the monitoring experiment	Graphs
VI (10)	Redesign and rules for a learning club. Joint session of village A and B.	Group discussion around several models, including the second stimulus and threshold models that support decision making of whitefly control actions.	Decision to organize first learning club meeting. Decision against the website.

article in 2011. The intervention was initiated in the pilot village A that has the largest number of densely located large greenhouse firms in the area. A total of six CL sessions were held between Feb 2011 and Jan 2012 (Table 1). The advisor-facilitator representing the local advisory organization negotiated the final agreements with seven greenhouse producers in the pilot village. The idea of the process in general terms was explained by framing the problem loosely as follows: there seems to be a need for a regional approach to the whitefly problem, but it is not known how this can be achieved. A total of nine year-round and five seasonal growers of tomato and/or cucumber, representatives of the research and advisory collectives, a local packing house, and a plant protection authority eventually participated in the sessions (Table 1). Table 1 shows how the data were obtained to answer the first research question: 1) How can the principle of DS be applied during a formative intervention aiming at solving a collective whitefly management problem that involves a large number of greenhouse growers and other actors?

The second research question inquires about the phases of the intervention, i.e. how did the process unfold and how did it contribute to transformative agency of the actors participating in the Change Laboratory? These questions were answered based on the audio recorded discourse data obtained during the six Change Laboratory sessions and consisting of a 13 h and 27 min discourse. The discourse was translated from the local dialect of Swedish into English and transcribed in its entirety for analysis. Forms of transformative agency in the discourse were identified in a previous paper (Vänninen et al., 2015) and selected excerpts were used in the current paper to describe the unfolding of the actors' interactions leading gradually to TADS. The selected quotes enable us to answer the third research question on whether transformative agency really took place in practice during the Change Laboratory process. In addition, graphic models and representations in the form of Power Point, Word, and Excel files created during the process of the Change Laboratory were also used as data. The collection and preparation of ethnographic and bioecological mirror data were facilitated by a sister project on bio-ecological aspects of the whitefly. We talked with growers, observed their working methods, and saw the interactions of the pest and its two environments: greenhouse crops and outdoor plants. Visits to companies in several villages allowed us to take photographs and observe the problem as it was manifested at different levels of severity. Economic mirror data were prepared based on an earlier grower survey on pest management costs in several firms. Four growers living in different parts of the area and one retired advisor were interviewed to understand better different viewpoints on the whitefly problem. Only one of the participant growers was interviewed, however the crops of three participants were monitored regularly for pests between the summer of 2010 and the first session. In this context there were numerous opportunities to talk with them and make notes on important points and learn about their pest management activity.

4.2. The method of analysis

The theoretical model suggests that the process of DS starts with the subject being exposed to a conflictive stimulus. In the study we understand a stimulus as a change in the environment expressed as mutually exclusive demands or expectations. We identify the stimuli from interviews and the discourse during the sessions. In the study, there are stimuli purposefully brought by researchers (e.g. first stimulus presenting different details of the problem), but we must also consider other stimuli to which growers are exposed before and between the sessions. These stimuli are depicted through interviews and conversations conducted before and between the sessions.

The conflictive stimulus may be interpreted and transformed into conflictive motives. Conflict of motives is expressed as mutually exclusive options to act. In Vygotsky's waiting experiment, the auxiliary artifact for resolving the conflicts was a clock. In this study, we were especially interested in the use of collectively produced models as auxiliary artifacts. With this analysis, we addressed the third research question: Did the principle of DS lead to building transformative actions that resulted in better whitefly management?

5. Results

5.1. Conflict of motives and first stimulus at the beginning of the intervention

The principal conflict of motives in the beginning of the intervention was the following: the growers had to solve the whitefly problem but could not do so using traditional methods incorporating chemical and biological control applied by individual actors (greenhouse growers) in isolation from each other. The situation that prevailed at the very beginning of the intervention included also a strong conflict of motives between seasonal and year-round growers regarding the concept of who was responsible for the problem and, consequently, who should solve the problem. Seasonal growers did not acknowledge the problem and their role in it to the same extent as year-round growers did and were therefore not willing to collaborate; while year-round growers acknowledged the problem but did not want to solve the problem alone.

The excerpt below is particularly interesting because it illustrates the nature of the first stimulus (the pest problem) and motives of seasonal growers regarding the whitefly problem before the intervention. A seasonal grower mentioned fleetingly that seasonal growers also should do something to prevent the pest from spreading outdoors and from there to newly planted year-round crops in the autumn but insisted that it is mainly the year-round growers' responsibility to reduce the whitefly problem.

Bert (session 1/speaking turns or quotes 17 and 20): “We have seasonal production, and that means that in wintertime it is cold in our nursery, so in practice we do not have any problem with whiteflies when we begin in [the next] spring. Later in the summer when **you** [=year-round growers] ventilate the greenhouse, whiteflies surely come in [to us] from outside. You cannot escape because it is never cold in the year-round nurseries… So, **we [seasonal growers] really do not have any big problem**. So how to get that issue solved… **You** ought to get rid of it in wintertime, more or less. Because you cannot do anything outdoors [in the summer]. It is wintertime [year-round growers] that should get rid of the pest.”

The key contradiction behind taking preventive actions by seasonal growers was that such actions involve costs, the redemption of

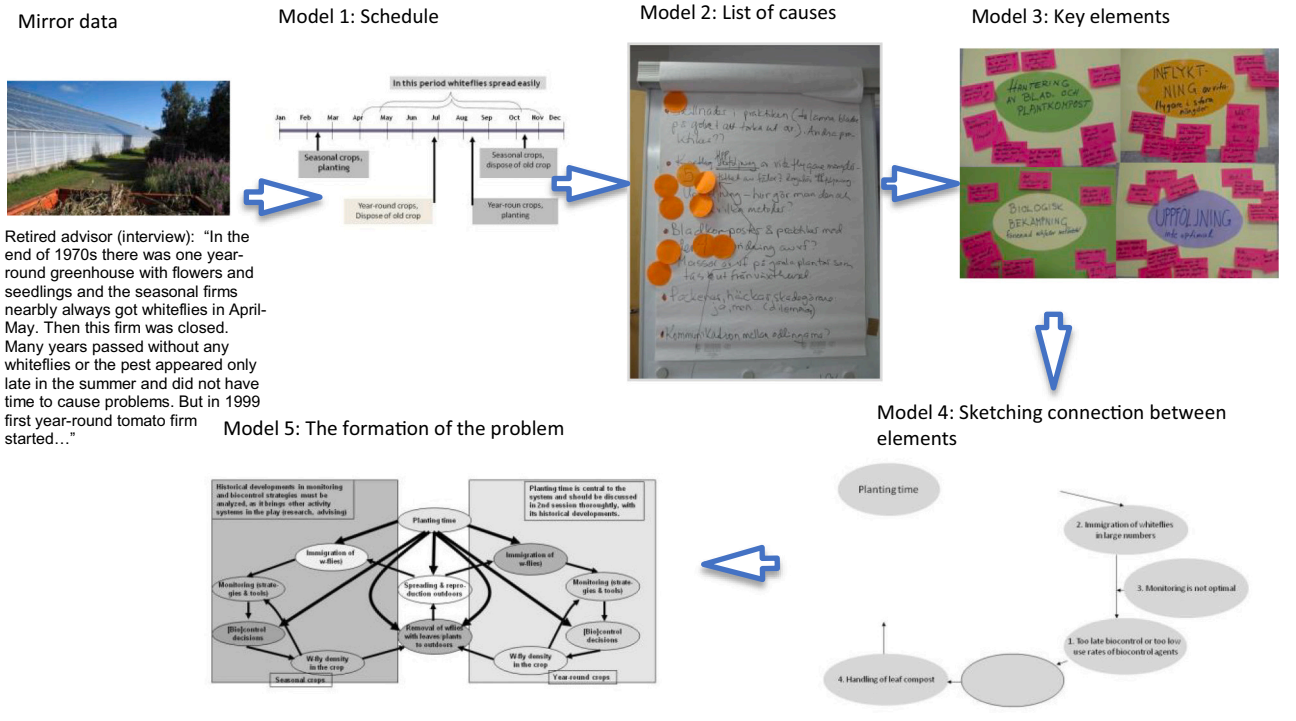

Fig. 2. Summary of the evolution from mirror data to the model of representation of the problem.

which is not guaranteed. Control always involves costs that must be covered by the reduction of crop losses achieved by the actions. If a grower does not acknowledge the losses preventive actions are not taken. So, the challenge was to measure whether preventive actions were worth taking or not. The first hints of the new emerging solution, "monitoring", appeared already in the first session. Two year-round growers pointed towards monitoring as the solution. However, monitoring remained at the level of an individual isolated action at this point of the intervention.

Year-round growers acknowledged their responsibility and mentioned that, for their part, they had already tried some actions to improve the situation. Paul (session 1/23): "But I think we have come a long way already this winter, thanks to Kirsti's monitoring [of the pest in our greenhouses]. After monitoring you know better in which greenhouse you must put in more or fewer biocontrol agents." Christian (year-round) supports Paul (session 1/27): "I have a similar situation… Kirsti visits me also and it is the same, like Paul talked about. We want to get rid of whiteflies."

Year-round grower Tom (the key change agent in the pilot village) reacts then, acknowledging the interdependence of growers in the pest issue, which would mean a different kind, i.e. systemic, approach to its control (session 1/33): "**I wish that we could break this circulation with pests that we exchange with each other**."

These quotes by the year-round growers express the conflict of motives between year-round growers' **strong desire to be independent vs. their desire to control the pest collectively**. As a group they felt the pressure coming from the side of seasonal growers to solve the problem, suggesting that the year-round growers were considered to bear the biggest responsibility for solving the problem. The year-round growers acknowledged that both types of growers should take action, but at this point the suggested actions were still taken independently.

The quotes presented above illustrate very well the learning challenge of the intervention. The reduction of the infestation of the whitefly required the collaboration of the two types of grower. However, seasonal growers neither acknowledged the problem nor saw themselves as part of the solution. The challenge was to transform the concept of the problem so that growers would design and implement collective solutions, involving both types of grower. The mutually exclusive options to act that represented the conflict of motives needed a resolution.

5.2. Construction of second stimuli to explain the problem more expansively

During the first session we introduced external stimuli in the form of mirror data to prompt discussion on what the precise problem was with the whitefly. How did the problem manifest itself? The mirror data were as follows: 1) excerpt from an interview with a retired advisor expressing the historical changes that led to the problem; 2) yearly control cost data from a seasonal grower on the cost of managing whiteflies coming from his year-round near-neighbor; 3) yearly variations in numbers of whiteflies in year-round greenhouses, showing the potential of learning from the differences that existed between firms. These data were important as they prompted the researcher-facilitator to ask whether growers shared information on what was happening in their greenhouses and why some had more whiteflies than others; 4) photos of undesirable practices that contributed to whitefly dispersal between firms, and 5) a timeline of planting schedules in seasonal and year-round crops to visualize the interdependence between growers through the whiteflies' potential to move between seasonal and year-round firms (Model 1: Schedule in Fig. 2).

After presenting the mirror data (first stimuli) and Model 1 (timeline), a discussion was initiated around the causes of the problem. The discussion prompted the stepwise construction of the auxiliary artifact (second stimulus), i.e. a model of the systemic nature of the whitefly problem and its different, interdependent components and how both grower groups contributed to it. The complete process of producing the second stimulus through a dialogical, interactive process between the practitioners and the interventionists required a total of three sessions. It began in the first session with the construction of a list of causes of the problem (Model 2 in Fig. 2), which helped the participants identify and share different perspectives regarding the causes. To delimit the problem and to focus their discussion, participants were asked at the end of the first session to vote for those causes that they saw as contributing to the problem the most. After voting, again the discussion returned to monitoring as practitioners reached an agreement that whitefly monitoring was pertinent for alleviating the pest problem, no matter what the eventual solution, as a whole, might be.

After the first session, the facilitators and the principal tutor continued working on the rudimentary systemic model (Model 3), producing two tentative models that could potentially work as a second stimulus in session 2 (Models 4 and 5 in Fig. 2).

5.3. Back to conflict of motives

In session 2, the discussion returned to lack of motivation of seasonal growers to take preventive actions. The facilitators decided not to show Model 4 to participants all at once, but instead they provided its four components on pieces of paper and made the participants discuss and complement them and arrange the components on the wall into a systemic model whose different parts were interdependent (Model 3, in Fig. 2). Although Model 4 was not used in the session, it helped the interventionists in the work of guiding the further development of Model 3 in session 3. The same concerned Model 5, a more advanced version, which helped the interventionists grasp better the collective elements of the whitefly problem. In Model 5, the interdependent elements were more numerous, but their mutual arrangement was not yet satisfactory. For example, planting time occupied a central place in the model. It was removed from the final model (Model 6 to be created for session 3) because growers considered that not much could be done about it.

Conflict of motives prevailed in session 2, as shown in a speaking turn by Tom (a year-round grower). He would have liked his seasonal neighbors to think of the interdependency of the firms, too. At this point, Tom spontaneously took to the white board to visualize his point of view with a graph – an attempt to model the interdependency of his and his neighbors' whitefly situations (session

2/311):

> "I don't want to blame anyone, but it is interesting to see how it works. I said to X that it would maybe be better if I were to give him plenty of whiteflies [in the spring] so that he would have had to do something" [from the very beginning to get them under control instead of just letting them be, resulting in a whitefly pressure on Tom's new crop in the autumn].

Tom's suggestion of solving the problem conflicted with the lack of his neighbor's intention of reducing whiteflies at the level of the whole village. Such conflict triggered tentative actions by Tom to solve the problem, but X's indifference was an obstacle.

5.4. *Activating second stimuli in critical situations*

In session 3, Model 6 was presented, and began influencing the discussion immediately:

Paul (standing in front of Model 6, session 3/1 & 29): "We are never going to get rid of the red arrows [refers to the outdoor component of the system and whitefly dispersal between companies], but these boxes [in the greenhouse] we can do something about!"

By 'these boxes' Paul referred to inappropriate or insufficient information that led to starting biological control too late or using too small amounts of beneficials, resulting in ineffective biological control.

The boxes in question suggested the solution elements lacking in the current system: a shared method to monitor whiteflies so that results between firms could be compared, systematic control plans of the pest, thresholds for decision-making for control actions, better understanding release rates for biocontrol agents guided by the thresholds and learning from each other.

Systemic understanding of the problem, prompted by Model 6, was reflected in the following speaking turns in session 3 and explicated into planned actions:

> Christian (year-round, session 3/303): "Let's say I was planning to take the plant heads off next week in one house. And now I have whiteflies there and I plan to use chemical A. But two weeks before I throw out the plants, maybe I should also use chemical B then [that works fast and removes the whiteflies before plants are taken out]? Wasn't it like that we were thinking?"
>
> To this Tom (year-round, session 3/309) responded by informing that he had already taken similar actions: "And we have also started… we used chemical A this week just to get the population down before it gets warmer."

Model 6 (Fig. 3) had seasonal and year-round crops presented separately but interdependent of each other. It also showed the indoor and outdoor components separated from each other but interacting. This step helped thinking what actually could and could not

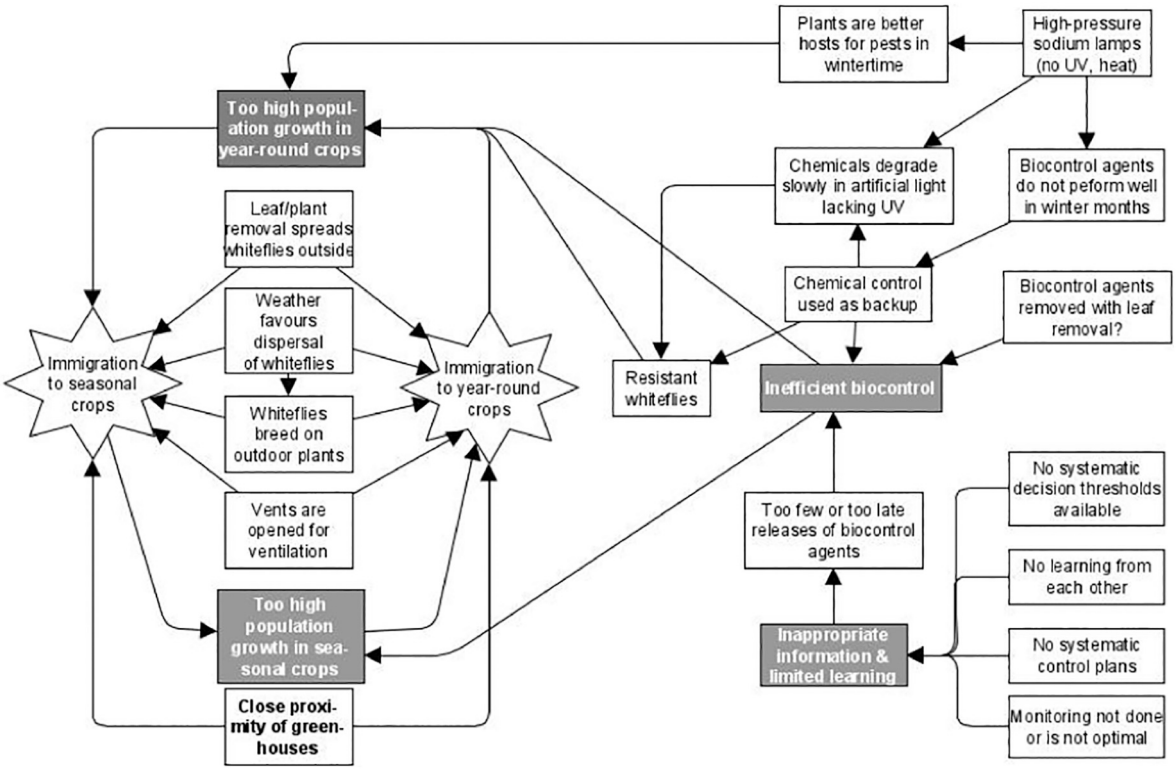

Fig. 3. Final form of Model 6 (systemic model of the whitefly problem).

be done with the pest.

Model 6 (Fig. 3) prompted the participants to move to the phase of solution designing. One of the advisors suggested that the advisor-facilitator should put the monitoring information in social media so that all involved could see it and learn from each other. Then a webpage as the medium for sharing information was brought up by the advisor-facilitator. There ensued a discussion about pros and cons of sharing monitoring and pest control data through a webpage. Then a competing option for information and knowledge sharing medium was brought up by a grower:

> Paul (session 3/131): "I think we should maybe have a small coffee meeting once a month, or every second month etc. Talk about the situation being experienced, what has been done and how it has worked".

Following Paul's suggestion, the discussion about information and knowledge-sharing among growers was expanded to include also improvements for information and knowledge sharing among the advisors' collective and including researchers in the new model of activity to interpret the statistical meaning of data.

Building Model 6 and complementing it in the third session initiated by participants the envisioning (Vänninen et al., 2015) of a new model of activity. Its key components emerged as a) information and knowledge sharing about the pest, and b) a standardized monitoring method to produce comparable data on pest densities in crops. The envisioning of the medium for information and knowledge sharing and collaborative learning continued through several steps in later sessions. By the 4th session, the object of pest management activity was reconstructed and collaboration in keeping the whitefly levels low [instead of eradication that was deemed impossible] was emphasized.

5.5. Return of the conflict of motives again

Against all expectations, the conflicting motives of keeping the individual old way and learning the new collective way to manage the pest resurfaced in the fourth session where only year-round growers appeared. This disappointing situation led the four year-round growers to doubt the intended collective approach:

> Tom (session 4/19): "No we cannot force them to join us. But it would be nice to know what the reason [for their absence] is (session 4, speaking turn 119). The big thing with the whole group… it looks like it is running into the sand!"

After the growers had vented their disappointment (with a high level of self-reflection and respect towards their missing colleagues), the influence of Model 6, combined with a graphical presentation of the new model of activity, continued and prompted new elements to be included in the latter. These concerned means of sharing information and knowledge about the pest infestation among growers. The suggested zone of proximal development (different learning paths that could be taken to solve the problem) and the table intended to discuss the remediation of the activity system in detail were only fleetingly looked at by the growers. They were too disappointed by the absence of the seasonal growers and considered it meaningless to discuss the details of remediation and different learning paths in the absence of their seasonal colleagues.

The return to the conflict of motives triggered by the Model 6 suggests not only that the process of formation of the conflict of motive is mediated by auxiliary artifacts but also that it is a dialogical bidirectional process in which the motive is constructed and deconstructed, being enriched during the intervention.

5.6. Deciding and taking transformative actions

After returning to the discussion about the conflict of motives in session 4, Model 6 induced suggestions of practical action that could help transform the problematic situation and facilitate breaking away from it for year-round growers. As one of the growers put it at the end of session 4: "We will continue!"

In session 5, the year-round growers and the advisor-facilitator succeeded in attracting two additional seasonal growers to experiment with standardized monitoring method over the summer (Vänninen et al., 2015) A large year-round firm suffering from serious whitefly problems and spreading them to their neighbors in another village joined in with monitoring and became an important testbed, which showed the effect of routine monitoring for control of the pest.

After the summer, growers from the two pilot villages joined together in session 6 where pest control thresholds were brought to discussion as further tools for decision-making. The systemic approach was summarized aptly by Tom, the key change agent among growers (session 6/46), who foresaw how the future would look due to implementing a collective approach:

> "We know that we exchange whiteflies, and they move from one place to another. So, it is important that everybody has them at a low level. In the case that one gets a smaller immigration, it is easy to think that one does not have any problem. The reason why one gets smaller immigration is because there is a group that keeps the population down!"

At this point Tom had no doubts that he was right with the need for having to do things differently. His words revived once more Model 6, but instead of pests, it was now information that spread between greenhouse firms, which turns into knowledge on how to use monitoring, decision-making thresholds and biological control to keep the pest densities constantly at a low level in all companies, with no free riders in the system.

6. Discussion

6.1. The process of transformative agency by double stimulation

Pedagogical theories that help facilitate agency are rare, but increasingly needed to help practical actors solve critical learning challenges that typically do not have obvious or 'correct' solutions. TADS offers a pedagogical theory of learning concerning the emergence and process of transformative agency "in the wild", i.e. in situations where practical problems of work-related or societal activities must be solved and often require collective action. Such problems require a pedagogy that allows learners to face such conflicts and to identify or construct artifacts that can serve as second stimuli and help them break out of the paralysis. The paradigm of TADS offers a starting point for a pedagogy of agentive actions and expanding possibilities (Engeström et al., 2020).

In the intervention described in this paper, it is possible to observe the general phases of TADS proposed by Sannino: conflictive stimulus, conflictive motives, use of an auxiliary artifact, and finally the activation of the conditioned connection, which are all necessary ingredients for transformative agency to unfold. However, some differences and specificities were observed. In the intervention the participants joined them with existing stimuli and motives originating from the time preceding the intervention. Researchers, through mirror data, helped to focus or to activate these stimuli and contributed to them becoming openly conflictive. Moreover, our case suggests that the process of motive formation is collective. Through dialogue, participants constructed and reconstructed their concept of the problem. It suggests that DS in the wild is essentially a collective process, and each phase is mediated by the community of learners.

Another difference refers to the process of formation of the motive. In the waiting experiment, the process of the conflictive stimuli becoming conflictive motives is relatively rapid (a question of minutes or hours). But as may be expected in the wild, such a process takes at least several sessions. The very fact that growers demanded the intervention and their earlier attempts to get the problem resolved by appealing to an external party suggest that the whitefly served as a motive for years before the intervention.

The process of learning and building transformative agency moved forward and backward during the process. The participants made use of auxiliary artifacts not only to envision possibilities of actions, but to formulate the problem in the first place – in other words, to form the problem. Moreover, in the intervention this process was bidirectional, meaning that the motivation was constructed and re-constructed with the use of the auxiliary artifact.

6.2. The use of models as an auxiliary artifact

In the intervention, the collaborative construction of representational models played a crucial role as auxiliary artifacts for the formation of transformative agency. It supported not only the process of formulating alternatives for actions, but also the formation and exposure of the motives in themself. During the intervention, growers, in collaboration with the facilitators and the tutor, elaborated a series of models, modified them into new, more complex developmental forms and variations, and in so doing, grasped their activity system and its problems (Engeström, 2015). For this process to take place successfully, representational models must be transformed into instruments. In other words, the artifacts should acquire characteristics of a tool, an instrument, or technology that is used by the participants for thinking and learning (Morgan & Morrison, 1999; Nersessian, 2008).

During the sessions, the interventionists tried to help recognize the limits of the current concept and practice, encouraging the growers "not to take the first solution" that is produced in the discussion. It was obvious that growers tried first to reach a solution by applying the prevailing approach to solving problems, which often involves fixed roles and individual responsibility (Virkkunen, 2006). According to Virkkunen (2006), two types of motive come into conflict during a transformation process: effective motives for the immediate solution of specific problems in an individuals' actions and understood motives for analyzing and developing the activity system as a whole. Thus, it is normal in the expansion process that it is difficult to let go of the prevailing approach first (see e.g. Virkkunen & Ristimäki, 2012). As important as it is, the modeling process, with all its steps, helped participants to go beyond mere bio-ecological and technical aspects of the problem that were presented in the mirror data, and understand the hidden, but unused, potential for sharing information and knowledge on the whitefly and its control among the grower community to achieve proper transformative agency aiming at change at the systemic level.

The gradual evolution of models seems to correspond to what Engeström and Sannino (2013) say about the use of auxiliary artifacts as instruments. They are usually used iteratively in a process where more than one auxiliary means is produced, one after another, to solve the problem, resulting in a chain of multiple auxiliary means. This is because seldom does the first decision of the subject and the resulting action solve the problem at hand. The use of models suggests DS as a powerful mechanism of volition through which human beings organize and control their behavior, whereupon voluntary action begins only when one masters one's own behavior with the help of symbolic stimuli (Sannino, 2015) The different models together functioned as "warping anchors" (Sannino, 2020b) with which the participants could pull themselves forward, from individual actions towards a collective solution for transforming their activity of pest management.

By making things visualizable and shared, Model 6 accelerated the natural process of communication and knowledge sharing among participants. But the question then became: is the model playing such a role only as a means of communication, i.e. for creating understanding of a developing concept internally (in one individual) or externally (between individuals), or is it also part of the solution concept that was developed in the process? Maybe it is both. We stated above that Model 6 was the end product of a mediator chain where DS was in action and produced a reframed understanding of the problem and initiated solution building. But Model 6 went further than that. Model 6 enabled a manageable thinking of the whitefly problem, and it can be further refined and expanded from its current form in future development efforts in the study area. Further development of the model is important because constraints and

resources needed to address a runaway object or a wicked problem such as the whitefly can change with time, necessitating re-evaluation of the problem (Peterson, 2009). Such change is brought forward by the removal of chemicals that provide quick control, which is already a reality in the Ostrobothnian system, or possibly the introduction of new, related pests such as the cotton whitefly (*Bemisia tabaci*) to the area (Cuthbertson & Vänninen, 2015).

The building of the systemic model alone was not able to convey the depth of the split between the two production forms among the grower community. The local advisor's fine tuning of the model to achieve a systemic representation of the whitefly circulation between the two production forms conveyed two things: it visualized the systemic nature of the whitefly problem without blaming one or the other production form, but it also came implicitly to contain the desired future state of the socio-ecological system, where growers of both production forms took responsibility for managing the pest due to their interdependence – i.e. transforming their pest management approach from individual actions to include also collective actions. In this way, the outdoor part of Model 6 came to represent the developmental possibilities as far as spreading information, instead of the pest, is concerned. But emphasizing the systemic nature of the pest problem and the interdependence of the growers, irrespective of their production form, hid, however, the prevailing tension between the two production forms, until session four. It was not until a serendipitous absence of all seasonal and some year-round growers from the fourth session that created a forum where year-round growers could reflect and analyze their perceptions on what the grower community thinks about the whitefly problem and why (Vänninen et al., 2015). The fourth session thus acted as an additional springboard that intensified efforts to get both types of producer on board in collective problem solving. This shows that Change Laboratory is an open-ended process that cannot be rigidly harnessed with a standard script, but is open to case-specific surprise elements that sometimes strongly influence the process (Engeström et al., 2013; Vänninen et al., 2015).

7. Concluding remarks

The article shows an application of the principle and method of TADS during an intervention. Such application has both similarities and specificities from the process of TADS under controlled experiments. Four elements that are considered essential for TADS were present in analyzed intervention: conflict of stimuli and motives, first stimulus, auxiliary breaking-away second stimulus, and actions that were initiated to improve the management of the problem at hand. The process of TADS in our study was more long standing, collective and bidirectional than the initial theoretical model of DS suggested. The problem in our case represented by the high infestations of whitely is more demanding than problems that have clearer boundaries. The study also shows that the process of TADS took place through a chain of different second stimuli that were taken up, producing a progressive re-definition of the model. It suggests that in more complex situations, the process of TADS may make use of several, rather than just a single second stimulus.

This article has examined the role of an evolving model as a second stimulus prompting TADS. The analysis has shown that models, as a second stimulus, played an important role in helping agents to grasp the whitefly problem (first stimulus) in a geographically compact greenhouse production cluster. The study reported a change from a narrow technical understanding towards a more systemically expanded view of the problem, which incorporated the role of the community of growers in the formation of the problem. The models worked as an end product that facilitated consensus among growers and eventually as a springboard that spread the expansion among growers. Rather than giving a ready second stimulus to be interpreted by the participants, the second stimulus was collectively constructed during the intervention. Their gradual construction throughout the intervention played an important role in prompting agency among the participants, making the learning process gradual and stepwise.

The study shows that models play the role of being a representation of the object and activity, being created for the purpose of gaining unexpected information or working out unforeseen potentialities of the object (Engeström, 2015). Building models requires interpreting, conceptualizing and integrating the parts that make the full model, and it is this process of constructing the model that involves learning about the problem at hand (Morgan & Morrison, 1999). Owing to such a process, participants have learned in our intervention, including the facilitators who became closely familiar with the pest situation in the growers' crops. As a consequence of the intervention described in this article, monitoring whiteflies using yellow sticky traps began to spread in the Ostrobothnian greenhouse cluster. It is nowadays a commonplace practice in both tomato and cucumber greenhouses, either handled by the growers themselves or outsourced from advisors (interviews conducted in an ongoing pest management project, led by Vänninen in the area in 2020 among the growers and advisors). The current study shows that the process of DS, through the use of models, can be used to construct transformative agency. Further studies are needed to investigate whether and how models also play a role during the implementation of consequential transformative actions.

Declaration of competing interest

None.

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