ORIGINAL ARTICLE

Seeing the system: Systemic gender knowledge to support transformational change towards gender equality in science

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Scholars agree that gender inequality is systemic and that participants in gender equality interventions need knowledge on gender inequality processes. However, a detailed view on the specific characteristics of this knowledge is as yet missing. This article aims to contribute to gender equality interventions by conceptualizing and visualizing systemic gender knowledge as an important condition for transformational change. Combining gender and participatory system dynamics literature, this article first introduces the concept of systemic gender knowledge. This concept captures two main characteristics that make gender knowledge systemic: knowledge on the interaction of gender inequality processes and endogenous thinking, here implying a focus on the organization as the relevant level of analysis. In addition to this conceptual contribution, the research contributes methodologically to the gender inequality intervention literature by designing a visualization process, translating written texts into system dynamics models which enable exploration of systemic gender knowledge. Finally, the research contributes empirically by exploring the systemic gender knowledge of participants in two science research institutes of a Dutch university, finding shifts in both characteristics of systemic gender knowledge. This enables researchers to discern whether gender equality

interventions lead to increases in systemic gender knowledge, thus supporting transformational change.

KEYWORDS

gender equality, interventions, participatory system dynamics, systemic gender knowledge, transformational change

1 | INTRODUCTION

This article contributes to gender equality intervention literature by exploring an important condition for transformational change: gender knowledge. Contemporary insights in gender equality interventions purport that sustainable gender equality can only be reached via transformational change: it is organizations that need to structurally transform the way they work in order to increase gender equality (Calás, Smircich, & Holvino, 2014; Ely & Meyerson, 2000b, p. 133). However, questions on how this transformational change is to be achieved, are at best partially answered. Reports on gender equality interventions show that progress is slow, difficult, context-dependent and everything but straightforward (Benschop, Mills, Mills, & Tienari, 2012; Dobbin & Kalev, 2016; Moss-Racusin et al., 2014; Parsons & Priola, 2013). In other words, there is no highway to gender equality. It is necessary to seek progress via small and often twisting roads. One of these roads concerns the knowledge that organization members have about processes and practices (re)creating gender inequality. Though knowledge never is a sole or sufficient condition for change, scholars do argue that it is important that organization members know how gender inequality results from gender inequality processes and practices (Benschop, Holgersson, Van den Brink, & Wahl, 2015; Benschop & Van den Brink, 2014; Bird, 2011; Bleijenbergh & Van Engen, 2015; Bustelo, Ferguson, & Forest, 2016; Ely & Meyerson, 2000b). The argument is that, once organization members are knowledgeable about how organizational practices produce gender inequality, 'these practices become potential targets for experimentation and change' (Meyerson & Kolb, 2000, p. 564). Thus, change efforts are argued to hinge on knowledge that recognizes and attaches importance to the role of gendered processes and organizational practices in (re)creating gender inequality. This gender knowledge is a central concept in transformational change efforts. Cavaghan (2013, 2017), for instance, shows how new gender knowledge competes with dominant gender knowledge, which most often does not support transformational change. Other scholars report how expert gender knowledge is disregarded or disreputed (Bleijenbergh, 2018; Moss-Racusin, Molenda, & Cramer, 2015; Van den Brink, 2015). However, a focused view on the specific characteristics of this gender knowledge is as yet missing. For instance, gender equality interventions often aim at implicit bias as the main lever for change (Vinkenburg, 2017), which possibly restricts the focus to interactions between people without addressing the organizational structures that produce inequalities. Transformational change is not likely to emerge from this narrow focus. Another example concerns the Gender Equality Training Toolkit, which explicitly aims at transformative change, but does not describe gender knowledge beyond the general 'knowledge about gender concepts and issues' (EIGE, 2016, p. 13). It is therefore important to explore what characteristics of gender knowledge scholars refer to when they discuss the need of knowledge to support transformational change.

This article aims to explore what gender knowledge participants need to understand, engage in and/or support transformational change towards gender equality. It contributes to the literature on gender equality interventions (Benschop & Van den Brink, 2014; Bird, 2011; Bleijenbergh & Van Engen, 2015; Britton & Logan, 2008; Bustelo et al., 2016) by coining the concept of systemic gender knowledge and detailing two characteristics of this knowledge, by developing an analytical tool to explore this systemic gender knowledge and by using this tool to explore the systemic gender knowledge of participants to two gender equality interventions. To this end, we first need to

conceptualize what gender knowledge supports transformational change. We will argue that two characteristics of gender knowledge are crucial in what we will call systemic gender knowledge. In doing so, we draw from both gender literature (Acker, 1990, 1992; Bird, 2011; Calás et al., 2014; De Vries, 2015; De Vries & Van den Brink, 2016) as well as participatory system dynamics literature (Antunes, Stave, Videira, & Santos, 2015; Lane, 1999; Vennix, 1996). Though system dynamics is prevalently known as a functionalist approach (Smircich, 1983), the more recently emerging participatory system dynamics is a European stream working from a social-constructivist paradigm. In this article we will first explain in depth why we think participatory system dynamics is valuable in conceptualizing systemic gender knowledge. Next, using participatory system dynamics concepts, we define what exactly makes gender knowledge systemic. Finally, we explore the systemic gender knowledge of organization members who participated in gender equality interventions in two research institutes of a Dutch science faculty. These interventions used a participatory system dynamics approach, facilitating organizational members in sharing and developing knowledge (Antunes et al., 2015; Lane, 1999; Lane, Munro, & Husemann, 2016; Stave, 2010; Vennix, 1996).

2 | A PROCESSES' VIEW ON GENDER INEQUALITY

Gender inequality processes are often referred to as being systemic. Acker (2006b) referred to 'the system of inequality' (p. 454) and the low representation of women being caused by 'system processes' (p. 457). Calás et al. (2014, p. 28) pose that attention for gendering processes makes it possible to observe: '[...] the production and reproduction of socially systemic inequalities', and De Vries (2015, p. 22) examines the role of male change leaders who are 'expected to disrupt systemic gendering processes'. A final example showing how gender inequality processes are characterized as systemic is from Bird (2011, p. 202), who states that participants in transformational change interventions should recognize 'how systemic barriers operate and why these barriers disproportionately disadvantage women'. But what exactly does it mean that gender inequality processes are systemic? The literature that labels gender inequality processes as systemic does not provide many specifics. Sociologist Joan Acker (1990, 1992) did describe the system underlying gender inequality: she conceptualized gender inequality as being sustained and (re) created by sets of interacting inequality processes, distinguishing structure, culture, interaction, identity and organizational logic. These processes proved to be a useful heuristic to analyse and understand the persistent construction of gender inequality in organizations (Benschop & Doorewaard, 2012; Dye, 2006), as 'a framework for seeing inequality' (Benschop & Doorewaard, 2012; Britton & Logan, 2008, p. 118; Dye, 2006). In other words, Acker's framework points out relevant organizational and societal processes active in generating and supporting gender inequality in organizations. For instance, Acker (2006b, p. 457) discusses an intervention reported by Ely and Meyerson (2000a). In this intervention, management did recognize that 'dysfunctional ways of behavior', such as rewarding heroism when enacted by men and denigrating women who behave in the same way, were bad for business, but they did not see that 'culture and organizing practices' caused this behaviour: '[...] the low representation of women in top jobs was still due to the failure of individual women, not system processes' (Acker, 2006b, p. 457).

However, this framework leaves room for further exploration and more specificity. First of all, Acker's (1990, 1992) gender inequality processes are widely — and almost routinely — represented as interacting, without explication on how, and with what effects they interact. Therefore, her framework leaves unanswered questions as to how to represent the interaction between the processes. In addition, it is unclear what processes need to be taken into account when analysing gender inequality in organizations. Acker herself was somewhat unclear on the boundaries of her framework (Dye, 2006). First, Acker (1990) included society in the framework processes, identifying 'the institutionalized means of maintaining the divisions in the structures of labor markets, the family, the state', referring to processes 'that produce gendered social structures, including organizations', and to society-informed organizational logic as the fifth process (p. 146). Later, Acker (1992) related four processes exclusively to gendered organizations, referring to a gendered substructure underlying the gendered processes. Gendered substructure thus replaced the fifth process of organizational logic. By conceptualizing gendered substructures, Acker further zoomed in on

processes of gender inequality at the organizational level. This is continued in Acker's later characterization of organizations as inequality regimes, in which she notes how societal inequalities originate in organizations (Acker, 2006a, 2006b). Calás et al. (2014) confirm the importance of an organizational lens for understanding gender inequality. Organizations are a site of gendering processes (re)producing gender inequality: '[o]rganizational practices and activities are concrete relational contexts where […] gendering processes may become visible' (Calás et al., 2014, p. 28). Yet, while the system of gender inequality is evidently not restricted to the organizational level, creating equality in work organizations requires a focus on that organizational level. So, gender inequality is systemic in the sense that processes producing gender inequality are ubiquitous, simultaneous and mutually constitutive, and occur at multiple levels: societal, organizational, individual.

We argue that a system dynamics perspective can help to elaborate on the interaction of the various processes of gender inequality. System dynamics acknowledges that a complex system (such as an organization) is more than the sum of its parts. It is the interactions between the parts of the system — the underlying structure of the system — which explain the behaviour of the system. System dynamics allows the examination of the interactions between separate processes, acknowledging their simultaneity and inseparability. In addition, system dynamics argues that there are no separate systems: it depends on the purpose of the discussion where to draw a boundary around a system (Meadows & Wright, 2008). This need to understand the interaction of the underlying processes of a system in order to make sense of the system as a whole is recognized both in system dynamics literature (Forrester, 1987; Meadows & Wright, 2008) as well as in gender inequality literature (Benschop et al., 2015; Vinkenburg, 2017). System dynamics literature enables us to elaborate on this principle, introducing the concept of systemic gender knowledge. We will do this by specifically drawing on participatory system dynamics literature, which supports an interpretive approach to system dynamics.

2.1 | Participatory system dynamics

Mainstream system dynamics is said to have a functionalist approach to systems as organisms (Smircich, 1983). Within this stream, a system dynamics model is 'an objective representation of a real system' (Barlas, 1996, p. 187). This model represents a structure which necessarily drives the behaviour of the system. According to the founding father of mainstream system dynamics, Jay Wright Forrester, system dynamics is designed not only to help people understand how systems work, supplying them with new knowledge, but also to change the way they think about such a system, and thus replacing existing knowledge with superior new knowledge (Forrester, 1987, p. 136). However, the field of system dynamics has seen the development of a separate stream of participatory system dynamics (Antunes et al., 2015; Lane, 1999; Lane et al., 2016; Stave, 2010; Vennix, 1996), away from a functionalist epistemology towards a more interpretive epistemology. This stream closely aligns with Smircich's (1983) description of the cognitive perspective on organization and culture, viewing organizations as knowledge systems, leading to research questions about the 'structures of knowledge in operation', research questions which can help 'those who seek to understand, diagnose, and alter the way an organization is working' (p. 353). In participatory system dynamics, the persons participating in the analysis of the organization analyse how a problem is the result of organizational processes.

We argue that the interpretive onto-epistemological footing of this emerging European stream of participatory system dynamics (Antunes et al., 2015; Barlas, 1996; Lane, 1999, 2000) makes this stream suited to inform our conceptualization of systemic gender knowledge. Participatory system dynamics aims to improve decision-making processes by involving 'multiple [participants] who often have different values, different views about the world and disagree about the problem formulation, management goals and decision criteria' (Antunes et al., 2015, p. 346). Participatory system dynamics brings participants together on the express acknowledgement that their opinions, views on and beliefs about the problem differ (Lane, 2000; Rouwette, 2011; Vennix, 1996). Participatory system dynamics enables participants to discuss these subjective meanings and share frames of reference in trying to establish the contextual rules that function in their organization. Thus, 'system dynamics methodology creates a common

language' (Antunes et al., 2015, p. 348), which 'allow[s] the meaning and importance of system elements to be nego-tiated' (Stave & Kopainsky, 2017, p. 33), helping 'human agents to create their social worlds via debate and the con-struction of shared meaning' (Lane, 1999, p. 517). Especially this characteristic of participatory system dynamics, enabling negotiations on multiple, subjective meanings, decides the method's fit in an interpretive paradigm. The group model resulting from these negotiations is a representation, not of a single and fixed reality, but of a shared, context-dependent and temporary reality: '[models] are contingent, related intimately to a specific problem and to the group that is attempting to address that problem' (Lane, 2000, p. 16).

2.2 | Systemic gender knowledge

Two characteristics of systems thinking crucially link to analyses of gender inequality processes. The first characteris-tic is firmly grounded in notions of causality. This causality is not linear, implying unidirectionality, but interactive, implying multi-directionality. Systems thinking supports the view that 'causal mechanisms both reinforce and under-mine one another, they operate alongside other (as yet) unknown mechanisms, and the combination of mechanisms differs from situation to situation' (Scott, 1995, p. 173, quoted in Lane, 2000, p. 13). These 'causal mechanisms', which we will refer to as processes, are interconnected in so-called feedback loops. Feedback loops graphically visu-alize how processes interact in a particular model, resulting from deliberations of a particular group in a particular sit-uation concerning a particular problem. The second defining characteristic of systems thinking concerns the boundaries of the system: the processes that are incorporated in the model explain the problematic behaviour of the system. We will refer to this characteristic as endogenous thinking. It means that a problem analysis does not point to 'independent forces from outside' in explaining how the system generates problematic behaviour (Richardson & Andersen, 2010, p. 314). This is not self-evident: 'People are far more comfortable blaming their troubles on uncon-trollable external causes than looking into their own policies as the central cause' (Forrester, 1987, p. 142). Scapegoating external processes is common in organizations, who tend to see themselves as a neutral stage for gen-der inequality processes occurring in society or between individuals (Calás et al., 2014). However, in order to under-stand how gender inequality processes are (re)created in the organization, the organization needs to be the central focus of analysis. Endogenous thinking bars the notion that a systemic problem can be understood by identifying external forces. In other words, if the problem that needs to be understood is organizational, endogenous thinking implies that the focus of the analysis is on the organizational level. Exogenous causes are excluded in order to better understand how the dynamics of the system that is the subject of analysis works (Richardson, 2011).

From these characteristics of systems thinking, two important characteristics of systemic gender knowledge emerge. First of all, systemic gender knowledge implies knowledge on interacting processes that are both cause and consequence of the systemic problem of gender inequality. Second, systemic gender knowledge displays endoge-nous thinking, implying that the (re)creation of gender inequality is analysed at the level at which the problem needs to be understood. We are now able to define systemic gender knowledge as an endogenous view on interacting pro-cesses (re)producing gender inequality.

In the following, we describe the process we devised to construct graphical system dynamics models from writ-ten texts, which we call visualization of systemic gender knowledge. The models resulting from this visualization pro-cess enable us to explore systemic gender knowledge.

2.3 | Visualization of systemic gender knowledge

In order to explore systemic gender knowledge, we need a language that allows us to detail and visualize the con-cept. Using the graphical language of system dynamics, we can show why, for instance, the phrase '*The proportion of women scientists in this institute is low because the general image of a scientist is masculine and because women choose to work part time*', displays less systemic gender knowledge than the phrase

It is a vicious cycle. A low proportion of women scientists in the institute keeps the masculine image in society of scientists alive, which negatively affects the attractiveness of science for women in society as a whole and hence of our institute.

Figure 1 provides the graphic translation of these two phrases into models. Model 1a in Figure 1 visualizes the first phrase. In model 1a we see that an increase in 'masculinity of image scientist' and 'women's choice for part time work' both independently decrease the 'proportion of women scientists in this institute'. As to the presence of both characteristics of systemic gender knowledge, we find first of all that this model does not display knowledge about interactions between processes, as there are no feedback loops. Secondly, the model does not explain how organizational processes re(create) gender inequality, as the focus is not on processes at the level of the organization. Therefore, the second characteristic of systemic gender knowledge, endogenous thinking, is absent in model 1a as well. The phrase that is visualized in model 1a does not display systemic gender knowledge.

In comparison, the second model in Figure 1, model 1b, shows systemic gender knowledge on both characteristics. First of all, in model 1b the processes interact: they form a feedback loop. The feedback loop explains that when the proportion of women scientists in the institute decreases, the masculine image of the scientist increases, which decreases the attractiveness of science for women in society. This will decrease the attractiveness of the institute, which in turn will further decrease the proportion of women scientists in the institute. Secondly, the example shows endogenous thinking, as the processes explain the (re)creation of gender inequality at the organizational level. The processes on societal level add to the understanding of inequality processes in the organization, because they are part of the feedback loop and thus not analysed as an 'external cause' of inequality processes in the organization.

These examples show how graphical language of system dynamics can be helpful in the exploration of systemic gender knowledge. Next, we describe our exploration of the concept in a case study of two gender equality interventions, which aimed to support transformational change towards gender equality in science.

3 | METHODOLOGY

We explored systemic gender knowledge in gender equality interventions in two different research institutes during action research at a Dutch university science faculty. Action research is based upon the notion 'that human systems could only be understood and changed if one involved the members of the system in the inquiry process itself' (Brydon-Miller, Greenwood, & Maguire, 2003, pp. 13–14). The top management of the science faculty was committed to participate in the action research, as the faculty struggled with an enduring numerical imbalance in men and
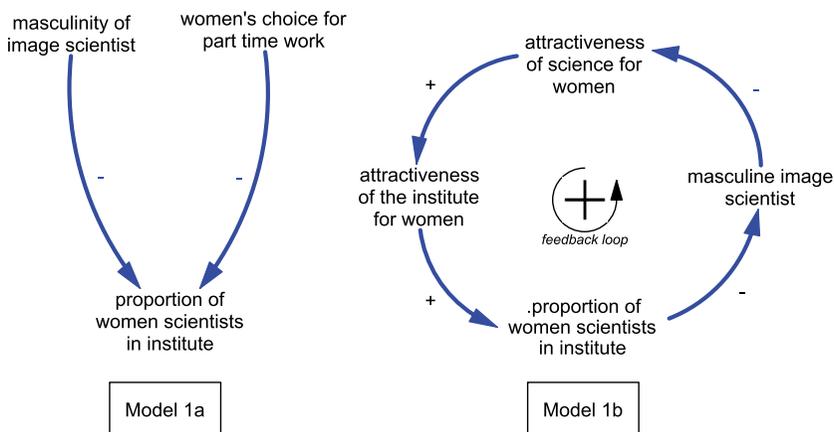

FIGURE 1 Modelling systemic gender knowledge

women scientific staff. The proportion of women scientific staff is below European and Dutch averages in science.[1] In the research institutes where the case studies were performed, the overwhelming majority of scientific staff consists of men. Statistics on the years 2008–2014, provided by the science faculty, show that full professorships in these institutes are, and have been, almost exclusively (around 95 per cent) occupied by men, whereas the percentage of men PhD students is around 80 per cent. This situation hardly changes over time.

Group model building, the method that was used in the interventions, is a form of participatory system dynamics supporting group learning (Vennix, 1996). During group model building, a facilitator supports participants in constructing a model that visualizes the dynamic structure of the problem that the participants aim to understand. Group model building is specifically employed with complex problems that are 'messy', meaning that different opinions and values of participants lead to varying descriptions of these problems (Vennix, 1996, 1999). Therefore, group model building aims to involve a diversity of participants. It depends on the problem whether participants are employees of a single organization, representatives from different organizations or participants with different experiences and backgrounds. Group model building engages participants in '[…] system mapping exercises aimed at opening up debates and promoting ideas exchange' (Antunes et al., 2015, p. 347). As participants' opinions differ on causes and consequences, on goals and methods, and on the question whether there is a gender problem at all (Benschop & Verloo, 2006; Heiskanen, Otonkorpi-Lehtoranta, Leinonen, & Ylöstalo, 2015), gender inequality qualifies as a messy problem (Bleijenbergh, Benschop, & Vennix, 2013). A pilot study showed that group model building is 'applicable to model the messy problem of gender inequality within organizations' (Bleijenbergh et al., 2013, p. 92), and it was described as a viable intervention for transformational change (Vinkenburg, 2017). Vennix (1996, pp. 5–6) argues that the process of building a model with a group of participants aims to create a 'shared social reality'. The intervention fits with participatory action research, as it aims to be 'democratic', enabling voices of all participants to be heard (Bleijenbergh & Van Engen, 2015; Van Nistelrooij, Rouwette, Vestijnen, & Vennix, 2012; Vennix, 1996). In addition, participant involvement in the construction of the model builds shared ownership of the resulting policy recommendations (Stave & Kopainsky, 2017). Commitment to the results of group model building is generally high (Rouwette, 2011).

Each intervention consisted of two four-hour sessions of group model building, planned two weeks apart. Both interventions were led by a two-person team of facilitators, consisting of either the first and second author, or the first author and another colleague. Participants were employees of two natural sciences research institutes, invited by the scientific directors of both research institutes with the aim of involving a variety of participants in different hierarchical positions, with different expertise and interests regarding the problem of gender inequality. The managers participating in the group model building in institute 1 were the dean of the faculty, and the scientific and managing directors of the institute. In institute 2, the scientific director attended. The other participants were academic staff employed by the institute (from full professors to postdocs) and support staff. In addition, in each intervention a different female gender researcher from the same university participated. We did not ask these gender researchers to fill out the questionnaires, as we did not research the development of their gender knowledge. Table 1 gives an overview of all men and women participants for each intervention. The goal of the interventions was to enhance

TABLE 1 Participants and questionnaires

Institute	Management		Faculty		Support staff		Subtotal		Total
	Men	Women	Men	Women	Men	Women	Men	Women	
Institute 1	2	1	3	4		1	5	5	11
Institute 2	1		4	6	1		6	5	12
Total # of participants	3	1	7	10	1	1	11	10	23
Questionnaires	3	1	4	5	1	–	8	6	14

team learning on the issue and to support the commitment to implementation of change (Bleijenbergh & Van Engen, 2015). Participation was voluntary.

3.1 | Data collection

The data set consists of verbatim transcriptions of the audio taped intervention sessions (16 hours) and of open questionnaires, filled out by participants both before and after the intervention. We used this open questionnaire to explore the systemic gender knowledge of participants (adapted from Fokkinga, Bleijenbergh, & Vennix, 2009). Twenty-one participants submitted their written answers to the questionnaires. Seven of them submitted only one questionnaire, either before or after the intervention, predominantly because they attended only one of the sessions. These incomplete sets were excluded from the analysis. Thus, the resulting data set consists of the questionnaires of the 14 science faculty staff members who submitted answers to the questionnaire both before and after their participation in the intervention (see Table 1). To guarantee anonymity of participants, we identify the participants with a pseudonym, indicating their position and their sex.

3.2 | Data analysis

In order to be able to explore the systemic gender knowledge of participants, and to explore possible shifts in this knowledge before and after the intervention, we interpreted participants' written answers to the open questionnaire before and after the interventions and visualized this interpretation into the kinds of models shown earlier in Figure 1. Thus, we achieved a graphical representation of their answers, visualizing our interpretation of their knowledge at that moment of gender inequality processes. This conversion from text to model took two steps for each individual participant.

The first step concerned identifying processes and determining how they interacted. To this end, we identified processes from the answers to three questions in the questionnaire: (i) 'What is, in your opinion, the key issue to be discussed?'; (ii) 'What are, in your opinion, processes causing this issue to persist?'; and (iii) 'What are, in your opinion, consequences of this issue?' We extracted the central problem from the answer to the first question. Next, we identified causal processes and their relations from the answers to the second question. We used textual markers, for example, indicating juxtaposition ('and') and subordination ('because', 'which'), as indications on how these processes were related. We next extracted processes that were the effect of the central problem from the answer to the third question in the questionnaire. When relevant textual markers were present, we linked these to the processes already identified. Finally, we established feedback loops when the answers indicated an interaction between processes, either explicitly or implicitly via phrases as 'ever more women', 'recurring effect' or 'something like a vicious circle'. This first step resulted in a graphical representation of the processes each participant identified, and of the way these processes were related to each other. When participants had identified interaction between processes, this was visualized in feedback loops. After this first step, we had a visualization of the processes and feedback loops which participants recognized before and after the intervention.

In step 2, we examined what level the processes addressed: society, organization or individual. For instance, we coded a process 'attractiveness for women' differently from a process identified as 'attracting women'. Though both processes address attractiveness of the field, we coded 'attractiveness for women' as a process on the individual level, because it is about what women apparently do or do not find attractive; it is a process that explains behaviour from an individual perspective. We coded the process 'attracting women' as a process on the organizational level, because it is about what the research institute is capable of. This second step resulted in all processes in the models being coded according to their level of analysis, and allowed us to specify to what extent the knowledge of participants showed endogenous thinking. Knowledge in which societal or individual processes are seen as unidirectional influencers of organizational processes shows less systemic gender knowledge than knowledge in which these societal or individual processes interact with organizational processes, as shown in model 1b of Figure 1.

After these two steps, 2 × 14 models gave information on the systemic gender knowledge emerging from the written questionnaires before and after the intervention. For each participant we explored the systemic gender knowledge emerging from the models we constructed from the written answers to the questionnaires before and after the intervention. This exploration also allowed a comparison between systemic gender knowledge before and after the intervention. An illustration of such a comparison is shown below.

3.3 | Exploring systemic gender knowledge

To show how we constructed models from the answers to the questionnaires, we specify the analytical steps we took with the questionnaire of faculty member Patrick. Figure 2 gives the models we built in order to visualize the systemic gender knowledge that emerged from faculty member Patrick's answers to the questionnaires. Model 2a in Figure 2 visualizes the systemic gender knowledge before the intervention. Patrick formulated the central problem as: 'Attracting and retaining more female staff and students.' We translated this into the boxed-in process: 'Capacity to attract and retain women staff and students.' Patrick formulated the following causes for this problem:

> Regarding inflow, image of the field. In addition, something like a vicious circle: few female employees, hence little appeal to students and possibly PhD-students, hence few female personnel, et cetera. A lone female student or employee can feel lost/a loner.

We visualized this in the processes above the central problem, with the arrows indicating that these processes are causes for the central problem. Finally, Patrick formulated the following consequences of the problem: 'A missed opportunity in finding potential for the institute as well as for society; A different atmosphere in the research group when there are only men.' We visualized these processes below the boxed-in central problem, the arrows showing that these processes are consequences of the central problem.

Model 2b in Figure 2 depicts the systemic gender knowledge after the intervention. Patrick now formulated the central problem as: 'The low proportion of women among staff & students.' We translated this into the boxed-in
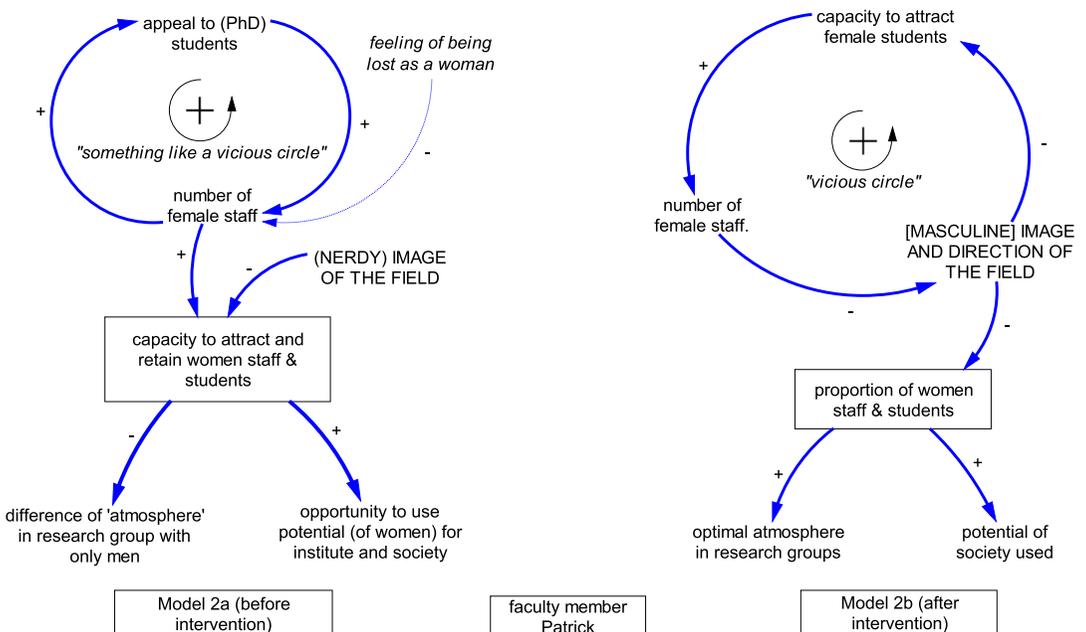

FIGURE 2 Modelling changes in systemic gender knowledge

process 'Proportion of women staff & students.' Regarding the causes for this problem, Patrick wrote: 'Vicious circle of image of the field, attracting few female students, hence having few female staff, which has an effect on image & direction of the field.' We visualized this in the processes above the central problem, with the arrows indicating that these processes cause the central problem. Finally, after the intervention, Patrick formulated the following consequences of the problem: 'Not making use of the full potential of society; suboptimal atmosphere in the various research groups.' We visualized these processes below the boxed-in central problem, the arrows showing that these processes are consequences of the central problem.

4 | FINDINGS

4.1 | Knowledge on interacting processes

The first characteristic of systemic gender knowledge is knowledge on the interaction of gender inequality processes. This concerns knowledge of feedback loops, consisting of processes that relate to each other as both cause and consequence. We explored changes with individual participants, in order to get a feeling of variations on the individual level, acknowledging that 'a change in knowledge' is dependent on context, subtle and fluid. Changes in individuals' knowledge at any given moment — whether indicating an increase or a decrease — should be seen in this perspective. In addition, we summarized the findings on all 14 participants, which required quantifying part of the qualitative material. Though we do realize that this means reduction, it supported us in comparing the changes in the characteristics of systemic gender knowledge on an aggregated level.

Faculty member Patrick (see Figure 2) described one feedback loop ('something like a vicious circle') before the intervention. After the intervention, he again described one feedback loop ('vicious circle'). So, concerning the first characteristic of systemic gender knowledge, knowledge on interacting processes, we see no change with faculty member Patrick. Describing the issue as a vicious circle, Patrick was one of three participants who described the causes and consequences of gender inequality in terms of interacting processes before the intervention. The other two participants stated that 'the issue has become a snowball' (faculty member Sidra) and that 'there is a back reaction' (postdoc Vicky). Most participants described only linear cause and effect relations before the intervention, summing up separate causes and separate consequences. Some participants did come close to 'closing the loop', connecting causes with consequences and vice versa. For instance, faculty member Hanna identified critical mass as one of the processes causing gender inequality: 'Critical mass problem: if an institute has very few women, it is not an attractive environment for women to want to work.' However, she identified the critical mass problem as a unidirectional cause for gender inequality at the institute, and only indirectly as a consequence as well. Thus, she did not explicitly close the feedback loop, and her analysis did not conform to the first characteristic of systemic gender knowledge. The same counts for faculty member Marian, who described a relation between six processes after the intervention, which formed a feedback loop but for one missing connection.

Concerning changes in thinking in interacting processes, one participant identified a single feedback loop before and two feedback loops after the intervention. Two other participants were constant: they identified a feedback loop before, as well as after the intervention. Faculty member Patrick was one of them, as we have already discussed. One other participant, female manager Selma, showed an increase in thinking in interacting processes, by describing a feedback loop after the intervention where she did not do so before the intervention. Transcripts of the discussion during the intervention support this change in Selma's knowledge. In a closing round at the end of the intervention, Selma was one of two participants who recognized explicitly that they increased their knowledge of the interaction of processes during the intervention. She said:

> The many-sidedness of the issues. [...] If you see everything in one model, then you think, o yeah, no, there is quite something to be done. [...] For me at least I see them all together [for the first time], and you think, it indeed all has an impact on each other. Then you become more aware of the multitude actually.

Aggregating all changes regarding the first characteristic of systemic gender knowledge, thinking in interacting processes, we find that the number of participants who showed this characteristic increased from three to four. The total number of feedback loops that these participants described, increased from three before, to five after the intervention. This slight increase aligns with reports in the literature that people in general have difficulty in thinking in feedback processes, even when schooled in systems thinking (Richardson & Andersen, 2010).

4.2 | Endogenous thinking

Endogenous thinking is the second characteristic of systemic gender knowledge. When the intervention aims at understanding how organizational processes (re)create gender inequality, endogenous thinking ensures a focus on dynamic behaviour of the organization. Societal or individual processes are included in interaction with organizational processes, and not seen as unidirectional causes of organizational processes. We found some endogenous thinking with six participants.

Starting again with faculty member Patrick, we found changes in endogenous thinking by comparing the models we constructed from his answers to the questionnaire before and after the intervention (see Figure 2). First of all, before the intervention, Patrick mentioned a process on the individual level as an external cause: *feeling of being lost as a woman*. After the intervention he did not mention this process. This is a decrease of focus on an individual process as external cause of gender inequality and thus an increase in endogenous thinking. Secondly, before the intervention he saw the societal process *(nerdy) image of the field* (displayed in capitals) as an external cause. After the intervention, he incorporated a similar societal process (also displayed in capitals) into the feedback loop, thus bringing it within the system of the organization. This indicates an increase in endogenous thinking.

We next present a discussion during the intervention to illustrate what deliberations and considerations preceded Patrick's increase in endogenous thinking. It concerns a fragment of a discussion that ranged for more than ten minutes on whether or not the institute could influence performance requirements in science. The discussion was intense, with participants frequently talking through one another. Junior faculty Sidra and manager Selma were most vocal in voicing the opinion that the institute could certainly influence science as a whole. However, manager Victor and faculty member Patrick explicitly disagreed. In the end, Victor conceded that, to the degree that internal male culture was influencing performance requirements, the organization had some control, but that the institute could not do anything about performance requirements 'in science as a whole'.

Turn	Participant	Quote
1	Victor	You won't succeed in changing performance requirements in science by appointing less male postdocs here.
2	Selma	No, but in this way you do sustain it, don't you? If you want to change something, you have to begin somewhere!
	[…]	
3	Victor	I wouldn't want to say that if I appoint more [female] postdocs, this will change performance requirements in science.
4	Sidra	But eventually it would, when all organizations would start doing that.
5	Victor	Yes, but that is not the point, it is about here. [Sidra and Selma both voice dissent]
6	Selma	There IS an interaction.
	[…]	
7	Victor	We, locally, cannot help much about the performance requirements, about the importance of the grant system.

(Continues)

Turn	Participant	Quote
	[...]	
8	Sidra	If this change in proportion of men and women occurs in all institutes [in our field], the whole culture of the scientific field will change. So, the influence is there, even though you can't measure it, in case you would appoint a couple more female postdocs here.
9	Victor	Well, the part that we control ourselves, that depends on the male culture inside, [...], but I think it is too much to say that we, here, can DO something about the performance requirements in science as a whole.

The negotiation revolved around the question: are performance requirements a cause of gender inequality in this organization that the organization cannot do anything about? This question exemplifies the core principle of endogenous thinking. When a model consists only of external causes pointing in a unidirectional way to gender inequality in the organization, the organization is a victim of these processes. Endogenous thinking offers two ways out of this. Either by incorporating external forces into the analysis, in such a way that the influence is bidirectional: society influencing the institute and the institute, albeit perhaps in barely perceptible ways, influencing society. The second option is focusing on organizational processes, leaving societal and individual processes out. The negotiation above signifies that managers Patrick and Victor were reluctant to extend the boundaries of the analysis to include societal processes. During the intervention, they preferred to restrict their analysis to organizational processes. However, after the intervention, Patrick did include the societal process ('[masculine] image and direction of the field') in his analysis of interacting organizational processes, indicating an increase in endogenous thinking.

Returning to other individual participants, in addition to Patrick, two participants showed an increase in endogenous thinking: Larry and Marian. Faculty member Larry identified only unidirectional processes before the intervention. After the intervention he connected processes on the level of the organization ('outflow after MSc degree' and 'role models for female students') with societal processes ('impression that science is a man's issue' and 'number of women scientists'). Faculty member Marian connected processes on all three levels after the intervention, which she had not done before the intervention.

One participant, faculty member Sidra, decreased in endogenous thinking. Before the intervention she said:

> The issue has become a snowball. The less women there are, the worse the atmosphere becomes and the less attractive it is for women. [...] working [here] is like entering the men's toilet by mistake and wanting to run as fast as possible.

This answer connected processes on both organizational ('number of women', 'quality of atmosphere') and individual levels ('wish to run away'). After the intervention, Sidra still focused on the organization, but left the processes on the individual level out.

Two participants remained constant regarding the characteristic of endogenous thinking in systemic gender knowledge: they pointed out both before and after the intervention that organizational and societal and/or individual processes were interacting.

Zooming out to all participants on an aggregate level, comparing the models before and after the intervention, we saw a shift in focus. The number of organizational processes that were identified increased from 66 before to 79 after the intervention, while the number of societal or individual processes decreased from 49 to 43. This illustrates that participants focused more on organizational processes as the relevant level of analysis after the intervention.

Concluding, the first characteristic of systemic gender knowledge, knowledge of interacting processes, translates in small changes in systemic gender knowledge of individual participants to the intervention. Regarding the second

characteristic of systemic gender knowledge, endogenous thinking, we also saw some shifts, generally towards more endogenous thinking. We conclude that in the interventions of our case study, the actual increase in systemic gender knowledge was visible, although modest. These minor changes indicate that we succeeded in visualizing systemic gender knowledge.

5 | DISCUSSION

This article aims to explore what gender knowledge participants to gender equality interventions need to understand, engage in and/or support transformational change towards gender equality. We contribute to the literature on gender equality interventions (Benschop et al., 2015; Benschop & Van den Brink, 2014; Bird, 2011; Britton & Logan, 2008; Bustelo et al., 2016) in three ways. We introduce the concept of systemic gender knowledge and detail two characteristics of this knowledge; we develop an analytical tool to explore this systemic gender knowledge; and we empirically explore the systemic gender knowledge of participants to two gender equality interventions.

The first contribution of this study is the notion of systemic gender knowledge as a key condition for successful gender equality interventions. We define systemic gender knowledge as an endogenous view on interacting processes (re)producing gender inequality, consisting of two main characteristics: knowledge on interacting processes and endogenous thinking. These characteristics enable us to describe what it is that makes gender knowledge systemic, a conceptualization that hitherto is not explicitly formulated in literature on gender equality interventions. With our conceptualization of systemic gender knowledge, we contribute to the literature that argues that organization members need knowledge of gendered processes and practices to effectively support transformational change (Bird, 2011; Bustelo et al., 2016; Lombardo & Mergaert, 2016). Building on Acker's (1990) pioneering framework of gendered organizations, in which she identifies the relevant sets of processes as structure, culture, interaction, identity and organizational logic, our introduction of systemic gender knowledge allows us to further elaborate how these different processes interact. We further underpin Acker's recognition of the importance of endogenous thinking and the linkages between societal, organizational and individual processes (Acker, 2006a).

The second contribution is methodological, as we develop an analytical tool to reconstruct participants' systemic gender knowledge, to be able to explore changes in this knowledge. By detailing how to translate verbal information into graphical representations, we extend the borders of qualitative content analysis. We show that the integration of participatory system dynamics with qualitative content analysis allows a detailed exploration of systemic gender knowledge.

The third contribution of this study is empirical. The concept of systemic gender knowledge helps to analyse whether the knowledge presented in gender equality interventions is able to support transformational change. When, for instance, an intervention only targets interaction processes between individuals, we know the knowledge presented is not systemic. Our exploration of changes in the systemic gender knowledge of participants in gender equality interventions showed modest increases. Thus, the case study shows that a gender equality intervention aiming at systemic thinking can lead to small increases in systemic gender knowledge. The increase of systemic gender knowledge is therefore a viable and identifiable goal for interventions in which knowledge production is key. The normative specification of systemic gender knowledge as the 'right' knowledge adds to the efficacy of transformational change interventions. In follow-up research, we may further explore the temporal aspect of gender equality interventions. Would similar increases be achieved with shorter interventions? Would investing more time lead to a larger increase in systemic gender knowledge?

We acknowledge that cognitive knowledge is at most a necessary and certainly not a sufficient condition for transformational change (Bleijenbergh, 2018). Further research is needed to examine whether the increase of systemic gender knowledge enables participants to gender equality interventions to take further steps on the path of transformational change. What is, for instance, needed to contribute to the translation of ideas into action? Eriksson-Zetterquist and Renemark (2016) recently argued that such translation is necessary for sustainable change, using

translation theory in their comparison of two gender equality intervention programmes. They concluded that not a top-down approach, but rather a localized approach involving all levels of the organization, contributes to the translation of ideas into action. This connects with the bifocal approach of De Vries and Van den Brink (2016), who stress the importance of the development of individuals as a strategy in transformational change efforts. Increasing the systemic gender knowledge of individuals might then be considered a strategy in transformational change. We can very well imagine that participatory system dynamics is exactly the kind of localized bottom-up approach, empowering participants, that is needed for translation of ideas into action. Further research on this idea is however necessary.

DECLARATION OF CONFLICTING INTERESTS

The authors declare that there are no conflicts of interests.

ENDNOTE

[1] Definitions and demarcations of (slightly) different scientific fields are manifold. We adhere to She figures (EU, 2013) in which the scientific field 'science' is a combination of (natural) science, mathematics and computing.

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