Participatory educational design

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Participatory educational design: How to improve mutual learning and the quality and usability of the design?

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Abstract

Many educational change proposals, designed to improve student learning, fail to be implemented in classrooms, which is a threat to the impact of educational policy on educational practice. This has led to a call for participatory educational design in which different stakeholders are involved in the generation and consideration of alternative learning environments, including physical spaces that better support learning. The development of tools to effectively engage non-professional designers in design activities is still in its early stages. In this article, we present two tools that can improve mutual learning of those involved in the design process and the quality and usability of both learning environments and supportive physical spaces: the laddering tool and the building block tool. Both are based on a new conception of teaching as bounded rational design in which a teaching practice is seen as a design to attain multiple goals simultaneously in a complex classroom context with limited available resources. By presenting a case from biology teaching, we illustrate how educational design processes between teachers unfold when they use these two tools. We argue and demonstrate that these tools are important for facilitating effective use of diverse contributions from different stakeholders, and also when involving students and architects in a participatory design process.

1 | INTRODUCTION

Many educational change proposals, designed to improve student learning, fail to be implemented in classrooms (Janssen, Westbroek, & Doyle, 2013). Hargreaves and Fink (2006, p. 6) put this succinctly: ‘Change in education is easy to propose, hard to implement and extraordinarily difficult to sustain’. Against this background, there is a call for participatory educational design in which different stakeholders (architects, educational designers, teachers and learners) are involved in the generation and consideration of alternative learning environments, including supportive physical learning spaces. This approach between teachers and students (Cook-Sather, Bovill, & Felten, 2014) and educational designers (Cober, Tan, Slotta, So, & Könings, 2015) and architects (Nordquist & Sundberg, 2013) aims to create a mutual learning process and high-quality and usable designs (Könings, Seidel, & van Merriënboer, 2014).

Participatory design is highly desirable for educational practice and policy to improve the effectiveness and efficiency of educational change processes. However, it is also very challenging (Simonson & Robertson, 2012). In decision-making processes in which many stakeholders are involved, it is common that they have different backgrounds and expertise or that only some members of the design team are experts in the domain. Multiple stakeholders can become part of the design process, but, in order to take on this role productively, they must be given appropriate tools to learn to know each other's context and goals and to co-design and choose alternatives. The accomplishments of individuals in participatory design processes are not only based on their capacities, but are also shaped by the tools they use (Brandt, Binder, & Sanders, 2012). In order to fulfil this important mediating role, the tools should be adapted to both the users and the goals of the participatory design process. In the literature for areas such as web design and urban design, we find many examples of tools to support these processes (Brandt et al., 2012).

In the area of participatory educational design, however, tool development to engage non-professional designers is still in its early stages. A tool will only be effective if it is adapted to both the tasks and the user (Simon, 1996). In this article, we focus on participatory educational design for classroom teaching. The first challenging task is to better understand each other's context, experiences and goals in such a way that participants can learn from each other. Second, it is to find ways to co-design new possibilities that are potentially effective and useful. Both tasks are challenging because participants often lack a common language to understand and share each other's experiences, expertise and goals. Moreover, participants who are not professional designers might find it difficult to define what they want if they do not know what is possible (Könings, Bovill, & Woolner, 2017, pp. 306–317; Simonson & Robertson, 2012). In order to be able to adapt tools to the capacities and working conditions of these two groups of stakeholders we need to know more about the nature of classroom teaching. We propose to view classroom teaching as bounded rational design in which teaching is seen as a design to attain multiple goals simultaneously in a complex context with limited resources (Janssen et al. 2013). Based on this conception, we present two theory-based tools that can facilitate these collaborative design processes of educational approaches and physical learning spaces. We developed a laddering tool that supports participants to map and share their multiple goals related to the design of learning environments (Janssen et al., 2013; Westbroek, Janssen, & Doyle, 2016). It describes and explains how people pursue simultaneously multiple goals related to a task (Kruglanski & Kopetz, 2009). We also developed a building block tool that helps participants to explore practical and effective possibilities for the design of the learning environment (Janssen, Grossman, & Westbroek, 2015; Janssen & Van Berkel, 2015). It consists of building blocks to construct, by recombination, a large diversity of productive teaching and learning processes and its structure is based on theories on modularity (Simon, 1996).

We show how these tools can be used in a design process to improve the quality and usability of learning environments, including physical learning spaces that better support learning. We illustrate these processes with a case of two Dutch biology teachers who work at the same secondary school, teach different classes, but share the same classroom. As we will elaborate later, educational expertise is represented in the building block tool that will guide the co-design of new teaching practices. This case shows that even participants with a similar background need tools to learn more about each other's practice and goals, as well as to co-design possible ways of teaching that suit their needs. The case also illustrates that participatory design of the learning environment is an important prerequisite for a productive (re-) design of their shared classroom. We also discuss the potential use of the tools in a participatory design with more diverse stakeholders

2 | TEACHING AS A BOUNDED RATIONAL DESIGN

Tools for participatory design should be adapted to non-experts users. We ground our tools in a new conception of the nature of classroom teaching as a bounded rational design (Janssen et al., 2013; Janssen, Westbroek, & Doyle, 2015). We propose that teachers are not able to optimise their designs solely to promote student learning because

FIGURE 1 Teaching practice as a bounded rational design

their rationality is bounded and so is the resulting design with respect to all three aspects that constitute the design: context, goals and resources (Figure 1).

First, classrooms in which teachers work are complex demanding places. They are not just places where teaching and learning take place. Classrooms have characteristic dimensions that constrain and guide teacher and student behaviour (Doyle, 2006). They are crowded places with individuals with different preferences, abilities, and agendas, in which a restricted supply of resources and time, as well as physical space are used to accomplish a broad range of objectives simultaneously. This complex classroom setting creates pressures on all teachers to attain multiple goals simultaneously, such as fostering individual student learning; covering content in time; increasing students' continuing motivation to participate; maintaining lesson momentum; promoting classroom norm;, and meeting their own needs (Kennedy, 2010, 2016). This partly context-derived multiple goal pursuit makes it impossible for teachers to focus solely on optimising student learning. Finally, there are always limits to knowledge, time and other resources which prevent teachers from exploring and weighting all the possible alternatives and their consequences. It is, for instance, impossible for the two secondary biology teachers in the study who teach multiple classes of 25+ pupils only twice a week (50 minutes) to know their particular learning needs for every new topic and to adapt instruction and tasks accordingly. Moreover, like all Dutch secondary school teachers, they have on average 15 minutes paid time to prepare a lesson (Bergen, Van Der Meer, & Van Der Otterlo, 2009).

This conception of teaching as a bounded rational design has important implications for the development of participatory design tools. A tool that will facilitate participants' understanding of each other's context and goals should take into account that teaching practice is not solely shaped by learning goals, but also by many other goals that must be taken into account simultaneously. Therefore the tool should provide insight into content and organisation of these multiple goals related to a teaching practice. A tool that supports participants to co-design new possibilities should also take the bounds of rationality into account. Teachers need time-saving procedures to design and enact new teaching practices in order to attain multiple goals with limited resources in their complex demanding classroom setting (Janssen et al., 2015).

Our view of teaching as bounded rational design draws on recent theories that explain how people in complex situations are able to make adequate decisions to attain multiple goals simultaneously despite limited time and resources (Campitelli & Gobet, 2010; Gigerenzer & Gaissmaier, 2011; Kruglanski & Kopetz, 2009; Lord, Diefendorff, Schmidt, & Hall, 2010; Shah & Oppenheimer, 2008; Todd & Gigerenzer, 2012; Wimsatt, 2007). Two strands of bounded rationality research are of particular importance for the development of tools for participatory design. First, work on goal systems explains how actions are embedded in a hierarchy of multiple goals and means related to a particular task

(Kruglanski & Kopetz, 2009; Lord et al., 2010). Our tool for facilitating participants' understanding of each other's contexts and goals draws on goal system research. Second, there is bounded rationality research on modularity as a fundamental strategy for managing complexity in a cost-effective and generative way by decomposing a complex system into building blocks and facilitating innovation by the recombination of existing building blocks (Simon, 1996; Wimsatt, 2007). Our tool for co-designing new possibilities draws on research on modularity.

3 | THE LADDERING TOOL TO EXPLORE GOAL SYSTEMS

Research on goal pursuit has mostly focused on the study of single, isolated goals and behaviours. However, research on goal systems has shown that, in complex situations, people pursue multiple goals simultaneously which all potentially compete for limited resources. Therefore in the fields of personality and social psychology, the question of how people's goal systems direct their actions, both consciously and unconsciously, has increasingly gained attention from the 1980s on (Austin & Vancouver, 1996; Carver & Scheier, 2001; Fishbach & Ferguson, 2007).

A goal system consists of a hierarchy of goals and means (Carver & Scheier, 2001).

Goals at the highest levels in a goal hierarchy reflect important aspects of someone's identity (identity goals) (Carver, 2012). These identity goals can be realised by principle goals, which, in turn, are implemented by even more specific goals which are closer to the specification of individual acts (see Figure 2c). Research on goal systems shows that the context greatly determines which goals will be activated (Shah & Kruglanski, 2008).The lower and therefore the more concrete the goals, the more context-dependent their activation. In general, a person will activate goals in a certain context when s/he estimates their desirability and feasibility positively in that context. For effective realisation, the goals in a goal system need to be synchronised. Goals are *vertical coherent* when somebody has the means to achieve a higher goal in a certain context. People tend to choose means which enable them to achieve several goals simultaneously and which do not conflict with other higher goals. In this case, we speak of a high level of *horizontal coherence*.

The laddering tool we developed allows participants from diverse backgrounds in educational design to construct a representation of each other's goal system and have a better understanding of each other's perspective on the learning environment. To construct a goal system representation we adapted the widely-used laddering method. This is a well-established procedure in the field of psychology for constructing personal goal-means structures (Grunert & Grunert, 1995; Veledo-De Oliviera, Akemi Ikeda, & Cortez Campomar, 2006). We adapted this method in a way that enabled participants to interview each other in order to co-construct each other's goal system in relation to their current teaching practice (Janssen et al., 2013). In addition, participants were invited to compare their goal systems. For a stepwise visualisation of the construction of a goal system see Figure 2a–c.

The interview proceeded as follows:

1. The interviewer asked the interviewee to bring a representative class to mind and then describe what he or she does in such a class and in what order ('from bell to bell'): 'What do you do subsequently?' We call these lesson segments. The interviewer writes every part of the class on a separate post-it note in the teacher's words (Figure 2a).
2. Then the interviewee is invited to state, for each lesson segment, why he or she thinks this segment is important. Every lesson segment can contribute towards several goals. Every *goal* – segment relation – is connected by an arrow. For each goal, the interviewer can ask again why the interviewee thinks this goal is important until the interviewee has 'arrived' at his/her most important goals (Figure 2b).
3. Then interviewees are invited to evaluate their goal attainment: What are you satisfied with (white boxes) and what are you dissatisfied with (grey boxes) (Figure 2c)?
4. Once multiple goal systems are constructed, participants can compare their goal systems in pairs. In this final step, they are invited to mark in their goal system the lesson segments and goals they share (black boxes in Figures 4 and 5). In addition, they are asked to list the other's lesson segments and goals that they consider important but are not yet part of their own goal system (black boxes at the side in Figures 4 and 5).

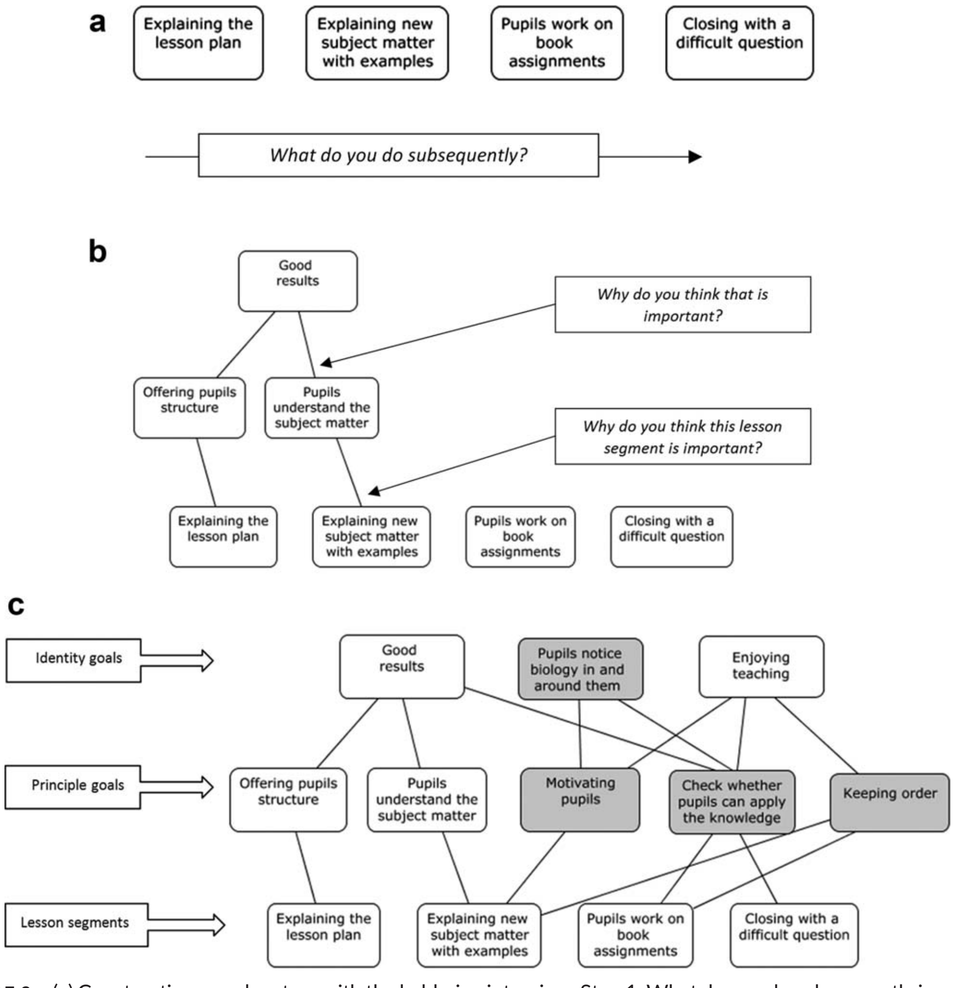

FIGURE 2 (a) Constructing a goal system with the laddering interview. Step 1: What do you do subsequently in your lessons? (b) Construction of goal system with the laddering interview. Step 2: What you think this is important? (c) Ilse's goal system

We illustrate the laddering interview and how it can facilitate a productive exchange of experiences and goals with the case of two biology teachers, Ilse and Hans. They both work at a secondary school (pupils aged 13 to 18) in The Netherlands and teach their biology classes at both pre-university and senior general secondary level. They share the same classroom and were not satisfied with the traditional classroom seating arrangement in rows. This seating pattern works well for lecturing, but not for other types of activities that both Ilse and Hans would like to do more of in the future, such as group work, practicals and individualised instruction. They do not have the budget to replace the existing furniture, but they know how to reorganise their classroom in a way that better suits their needs. They interviewed each other with the laddering method to explain these needs.

We then briefly describe Ilse's goal system (Figure 2c). It shows clearly how her classes used to proceed. After Ilse's explanation of the new subject material, pupils would start doing assignments from the work book. Ilse usually ended the lesson by asking a difficult question to see if the pupils are able to apply the material. Her evaluation of her goal system (step 3 of the interview procedure) revealed that she was generally quite happy with this approach (indicated by the white boxes). There were, however, some goals she found difficult to attain with her current approach (grey boxes). For instance, it bothered her that some pupils did not pay attention to her explanation. She had to warn students regularly and sometimes ended the explanation segment of the class early and let the pupils work by themselves. She also regretted that she had not yet been able to put an important goal of hers into practice. Rather than let

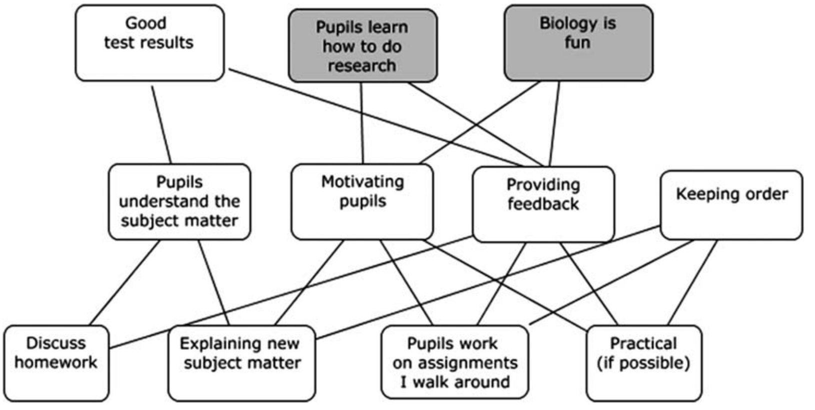

FIGURE 3 Hans' goal system

the pupils realise that biology is constantly present in themselves and their surroundings, Ilse was under the impression that pupils viewed biology as something from a book.

The goal system of the other biology teacher, Hans, revealed a fairly similar lesson structure (Figure 3). Moreover, Ilse and Hans shared many goals that were partly derived from the regular demands of classroom teaching, such as wanting students to understand theory, pass the test and be motivated and that classroom order be established and maintained. There were, however, some important differences. For instance, Hans emphasised the importance of teaching pupils how to ask and answer questions in order to develop a scientific attitude. Like Ilse, he was fairly satisfied with his current teaching, but saw room for improvement in supporting students to develop a more inquiring mind.

After co-constructing each other's goal system, Hans and Ilse talked about both similarities and differences in their goals and teaching approach and this triggered a mutual learning process (see Figures 4 and 5). Hans, for instance, liked the way Ilse ended her lesson with a difficult question to check pupil's understanding and decided to implement this in his own lessons. Ilse liked Hans' idea that pupils should learn to ask and answer their own questions because she thought that could be an important way to attain her most valued goal: helping pupils to become aware that biology is everywhere.

4 | EXPLORING PRACTICAL POSSIBILITIES WITH THE 'BUILDING BLOCK' TOOL

We not only need a tool to elicit goal systems, but we also need a tool that enables participants to explore and co-design new possibilities for teaching. This tool should meet three criteria. First, it should be *generative*. It should enable participants to keep exploring new ways to design instruction and generate possibilities that they will consider as *practical*. Someone will only consider a new teaching proposal as practical if cost-effective procedures are available to

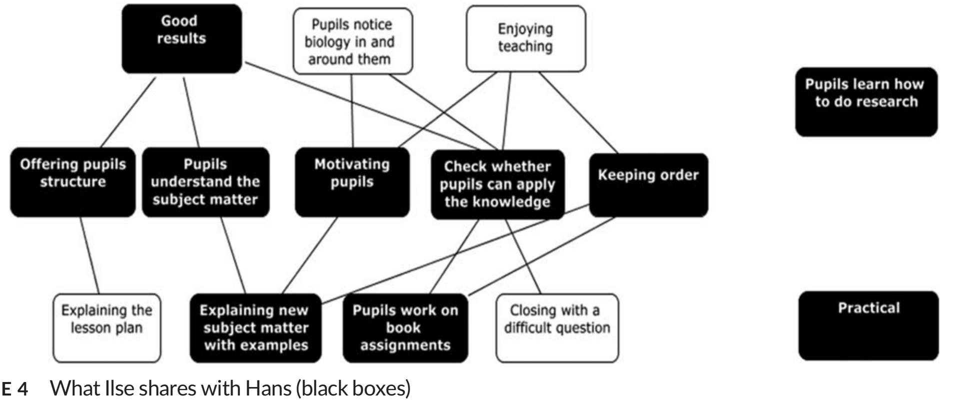

FIGURE 4 What Ilse shares with Hans (black boxes)

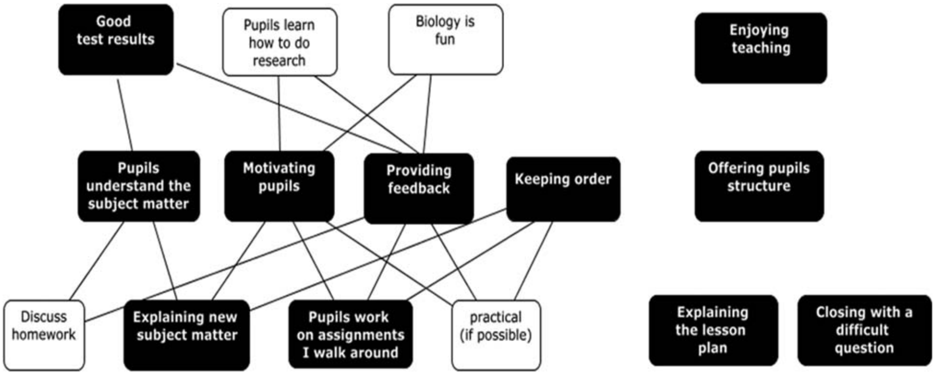

FIGURE 5 What Hans shares with Ilse (black boxes)

translate these new ideas into educational practice and if the proposed changes fit his/her goals and circumstances (Janssen et al., 2015). Finally, the generated educational design alternatives should be potentially *effective* in stimulating student learning.

Bounded rationality research on modularity provides important insights to develop a tool that meets these three criteria. Modularity refers to a general strategy in which a complex system is decomposed into building blocks, or modules, and recomposed in different ways to innovate the system at hand (Simon, 1996; Wimsatt, 2007; see Janssen et al., 2015, for a recent interdisciplinary overview of the idea of modularity and how it can help to address many recurrent tensions in teaching). Modular innovation is a pervasive feature in both the natural and man-made world. With a limited number of building blocks and rules for re-combining them, a great diversity of innovations can be generated in a cost-effective way. Language is a prime example of modular design at different levels. Letters can be recombined into words and with a limited lexicon and some syntactical rules we can generate a vast number of texts. We find the most impressive demonstrations of the innovative capacity of modularity in nature. Every kind of molecule in the universe is assembled from a hundred-odd chemical elements. And an alphabet of four nucleotides in DNA suffices to encode the 20 amino acids and these, in turn, by recombination construct the innumerable proteins of all living beings. But many innovations in complex man-made systems such as cars, houses and computers are based on slight adaptations and a recombination of existing components.

Although modularity plays a central role in many design professions, its potential for educational design in general and for participatory educational design in particular remains largely untapped (Janssen et al., 2015). Over the years, Janssen has developed and tested a modular building block tool that enables participants to generate new practical and effective designs for teaching (Janssen & van Berkel, 2015). The basic set consists of four building blocks and two rules.

Our building block tool consists of the following four blocks: explanation, worked-out example, part task, and whole task. In an explanation, subject matter is presented in general terms. In contrast, in a worked-out example, subject matter is illustrated or demonstrated. A part task is an assignment that invites pupils to reproduce or apply only a small part of the subject matter that needs to be covered. In contrast, a whole tasks stimulates pupils to apply most of the subject matter in a new complex situation. Many teachers typically sequence these building blocks in the following way: explanation → worked-out example → part task(s) → whole task(s) (Janssen & Van Berkel, 2015). Consider for example how many biology teachers will teach about the layers of the skin (Figure 6: regular). They will first *explain* the three layers of the skin, often followed by *worked out examples*: for instance, applying knowledge about the layers of the skin to understand how skin care products work, followed by *part tasks* for students to reproduce or apply parts of the subject matter, for instance a filling in the blanks task, followed by more complex *whole tasks* that invite students to apply most of the newly-learned subject matter about the layers of the skin in new situations, for instance how deep do you have to stick a needle to have a lifelong tattoo?

This traditional type of teaching, however, has often been criticised by educational designers because it does not meet the criteria for effective teaching (see Janssen & Van Berkel, 2015, for an extensive elaboration). Based on

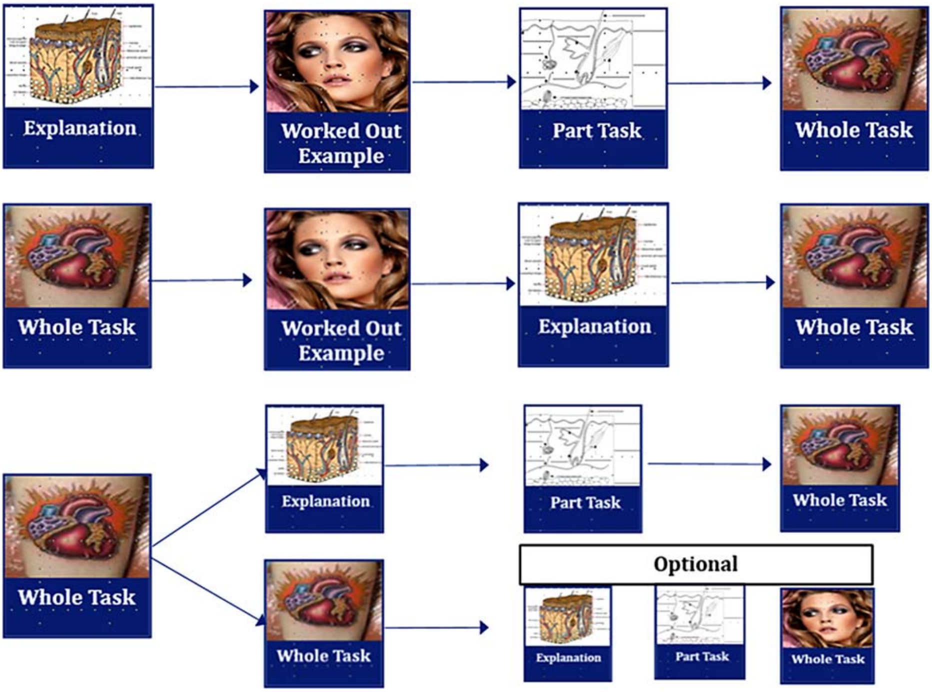

FIGURE 6 Generating multiple design alternatives by reversal and selective combination of existing building blocks. The first row represents a regular lesson structure for the topic of the layers of the human skin. The second row represents a similar lesson, but with the whole task upfront. The third row represents a more adaptive way of teaching about the human skin, by selective omission of certain building blocks. After the introduction of the whole task, pupils can choose either an explanation by the teacher before they work on the whole task, or they start immediately working on the whole task using explanations and part tasks in their textbook as support if needed [Colour figure can be viewed at wileyonlinelibrary.com]

research on effective teaching, we summarised the main criteria for teaching effectiveness (Boer, Janssen, & Driel, 2016; Janssen & Van Berkel, 2015) (Table 1). Students only learn effectively when given the opportunity, want to learn, are able to learn, and when there is a certain sense of mutual trust. Two criteria can be identified for each of these main categories. We formulated them as questions that students should be able to answer affirmatively after having participated in class.

In order to meet criteria for effective teaching, many educationalists argue that teaching should not start with an explanation of new subject matter, but with the introduction of a whole task (Kirschner & van Merriënboer, 2008; Merrill, 2012). Learning in a context of a whole task will enhance the opportunity to practise what pupils are expected

TABLE 1 Criteria for effective teaching formulated in questions that pupils should be able to answer affirmatively

	Criteria	
Opportunity	Purposeful Clarity	Were you able to practice what you have to be able to do? Did you know what was expected of you?
Willing	Interest Expectation of success	Did you think it was interesting? Did you think you would be able to do it?
Being able	Challenging Feedback	Was it too easy, or too hard for you? Did you get informative feedback how to proceed?
Trust	Respect/care/understanding Autonomy	Did you feel taken seriously? Did you have freedom of choice? Did you feel in control?

to do, it provides them with content-related motives for learning, and they will quickly discover what they do not know or cannot do and therefore what they still have to learn (Janssen & Van Berkel, 2015; Merrill, 2012). In addition, many educationalist have argued that the success of teaching largely depended on the fit between task demands and student potential and therefore support for working on these whole tasks should be adapted to individual student's needs (Belland, 2014; Corno, 2008). This led us to formulate two rules for combining the building blocks: 'whole task first' and 'adaptive support' (Janssen & Van Berkel, 2015).

For each rule, we also added a crucial heuristic that allowed participants in educational design to implement these principles in a cost-effective way. Whole task first designs can be developed with the reversal heuristic that advises participants to select an already existing whole task (for instance the tattoo task, Figure 6) which is often either assigned at the end of a lesson or unit or skipped and bring it to the fore to start the teaching about the new subject matter. The selective omission heuristic helps the participants to implement the adaptive support principle. This heuristic involves considering all remaining lesson segments/building blocks (explanation, part tasks, worked out examples) as support for completing the whole task. The pupils only have to complete these lesson segments if they need them to successfully complete the whole task. (See for instance alternative 2 in Figure 6). After the introduction of the tattoo task, students can choose to either follow the teacher's explanation about the layers of the skin or start working on the tattoo task immediately, using explanations and part tasks in their textbook if needed.

Figure 6 illustrates how this building block tool consisting of four building blocks and two rules allows for the development of several new teaching designs by re-sequencing and selectively omitting existing building blocks. The examples we describe in Figure 6 are still relatively straightforward. The teacher determines the whole task, this task is about a limited amount of subject matter and the options concerning adaptive support are also limited. However, the two rules and four building blocks can also produce different and more complex forms of teaching, depending on the amount and nature of the content covered by the whole tasks and to what extent pupils have a say in determining the whole task(s) on which they are working. Moreover, adaptive support can be implemented in various forms, depending on who controls it, how much support is provided, and to what extent the support is personalised (See Janssen et al., 2016 and Janssen, et al. 2013 for an application of these heuristics in the context of a teacher training programme in which student teachers are supported to convert traditional cookbook lab in science classrooms into open inquiry labs).

Ilse and Hans used this building block tool to explore new ways of teaching that would fit their goal system and circumstances. They first characterised their regular lesson structure with the building blocks. Ilse realised that her difficult question at the end of the lesson was often a kind of whole task. The whole task first by reversal rule made her wonder if she could improve her pupils' motivation during her explanation simply by starting her lesson with the introduction of the whole task. For instance, she used to end an ecology class by challenging pupils with the following statement by Marianne Thieme (the leader of the Dutch Party for the Animals): 'A vegetarian in a Hummer is more environmentally friendly than a 'meat eater' on a bicycle'. The pupils needed to explain, using the ecological concepts they had just learned, if Marianne Thieme could be right or not and why. She now decided to start her ecology classes with this statement and then ask pupils to discuss briefly in pairs what they thought about it and why before explaining ecological concepts the way she regularly did. Pupils completed some part tasks and finally tried to complete this whole 'Thieme' task using the ecological concepts they had learned.

Hans, on the other hand, first saw new possibilities for improving his practical by using the adaptive support by selective omission rule. In his regular practical, pupils often followed a step-by-step manual to answer the research question. Not because he thought that this was the best way to develop pupils' inquiring minds, but simply because he only had 50 minutes to complete a practical and he thought that it was important that all students should be able to finish this practical in time with reasonable results. The selective omission heuristic made him realise that he could satisfy these more practical goals and at the same time invite pupils to think first about how to answer the research question. He did not begin by handing out the manual, but let pupils think for 5 to 8 minutes about a possible way of answering the research questions. Then he gave them the manual. They compared this method with their own and, if necessary, revised their method and proceeded with the practical.

The building block tool also made Ilse and Hans realise that they could both better achieve their own most important goals by allowing pupils to select or formulate their own whole tasks related to a particular unit.

The laddering and building block tool not only helped Hans and Ilse to generate many new practical and potentially effective ideas for expanding their teaching repertoire, but also helped them to get a better sense of how they would like to reorganise the physical organisation of their classroom. This reorganised classroom should afford them the possibilities to enact their now enriched teaching repertoire in a flexible way. They consulted easy-to-access expertise on classroom seating arrangements, starting with a Google image search with classroom seating arrangement as the search phrase. They decided to reorganise their traditional seating arrangement with rows of tables facing the front of the room into a 'Double U' arrangement. Hans and Ilse believed that this arrangement still worked well for presentations by both teacher and pupils and for a large group (25 +) of pupils. They also found this arrangement attractive because it encouraged discussion and participation and made it easy for the teacher to observe and provide one-to-one help. Moreover, by simply turning the chairs, it also allowed for group work.

5 | CONCLUSION AND DISCUSSION

In this article, we introduced two tools to facilitate participatory educational design for classroom teaching based on a conception of teaching as bounded rational design. The laddering tool helps participants to have a deeper understanding of each other's experiences and goals with respect to teaching, which, in turn, is a precondition for a productive mutual learning process. The resulting goal system representations provide a window into participants' instructional decision making. By moving upward in the goal systems, participants get a better grasp of the higher level goals that motivate them. By moving downwards, they develop a better sense of the many considerations that afford and constrain the pursuit of multiple goals.

Explaining and sharing each other's goal systems enable participants to frame a joint problem space for developing new teaching possibilities. The modular structure of the building block tool can support non-professional designers to generate new potentially practical and effective learning environments and aligned physical learning spaces. The building block tool also fulfils another essential role for productive participatory design: It provides participants with a much needed common language to talk about current and desirable teaching practices (Grossman & McDonald, 2008).

In our case, two teachers were involved in a co-design project with indirect input from educational designers, as expert knowledge about effective teaching was represented in the building block tool. Both the laddering and building block tool can also support participatory educational design activities that include other participants like learners (Janssen et al., 2016). Because both tools help participants to answer questions about what, how and why to teach they indirectly facilitate the design of supportive physical classroom environments. However, in order to guide the design of physical classroom environments more directly, our tools need to be complemented with modular tools to design physical learning spaces, for instance a tool for designing seating patterns based on a limited set of building blocks and rules.

Learning scientists more and more replace a 'theory first and practice second' approach with forms of participatory design research in an effort to solve real school problems (Fishman, Penuel, Allen, Cheng, & Sabelli, 2013). These approaches share a focus on persistent problems from multiple stakeholders' perspectives, a commitment to iterative and collaborative design and often a concern with developing capacity for sustaining change in systems. However, in order to engage non-experts, like students and teachers, productively in the processes of participative design, tools are needed that are adapted to both the tasks and the capacities and working conditions of the participants. Practical tools based on a bounded rational conception of teaching are currently still an important missing link to support participatory educational design processes that result in designs that not only support student learning effectively, but are also practical for teachers to implement (Janssen et al. 2013). By facilitating effective use of diverse contributions from different stakeholders, these tools support the process of educational change and by consequence facilitate impact of educational policy on educational practice.

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