Chapter 5 Model Formulation

This chapter presents the procedure of the conceptual model formulation, which can be divided into four stages. Firstly, the requirements identified in the previous chapters are summarised. Secondly, the creative techniques selected to formulate the conceptual model and to address the NPD model are described. Thirdly, the formulating procedure is explained. Finally, the new conceptual model and its implementation are demonstrated.

5.1 Conceptual Model's Requirements

According to the principal findings, there are three requirements that must be addressed in the conceptual model of the Smart Clothing development process as shown below.

1. Challenging the participants to go beyond the existing creative boundary.
2. Clarifying the contributions and responsibilities of every participant involved.
3. Incorporating the context of Smart Clothing development, such as a multidisciplinary approach and a high level of collaboration.

Based on these requirements, it can be seen that the new conceptual model cannot use any structure of the existing generic models demonstrated in chapter 1 and 2. This is because these existing models are focused on providing a basic guideline, which can be adapted to any type of product developments. By dividing the product development tasks into certain stages, the generic models are simple and easy to understand. However, it does not clarify the contributions and responsibilities of each participant, which are crucial for the multidisciplinary approach. Moreover, the generic models promote established activities rather than challenge the developers to explore the new way of thinking and working.

It is clear that a new conceptual model requires not only a new structure but also a new way of working. Whilst the generic model provides a basic guideline and a checklist, the new model helps the participants solve the problems, which occur specifically in Smart Clothing development, such as integrating the differences among the developers. Therefore, it is possible that the new model will be used in conjunction with the existing models. Since this conceptual model aims to overcome the imbalanced contribution caused by the restricted creative boundary and conventional thinking, it focuses on the activities at the front end of the NPD process, such as researching and strategic planning. As a result, this model will not cover the problems of the later stages, e.g. production.

In order to fulfil the first requirement, several creative techniques are selected and addressed in formulating the new conceptual model. As these techniques change the way people think and work by suggesting new behaviours (e.g. activities, procedures, etc), they are more acceptable, effective and quicker than the methods that set out to change the personalities (De Bono, 2000b). The creative techniques are not only employed to help the participants go beyond their creative boundary, but also used as a procedure to formulate the new conceptual model itself. Further details about the creative techniques are explained in the following section. To achieve the second requirement, the new model must concentrate on responsibility and contribution of each participant rather than describing a sequence of the activities like most generic models. Finally, to accomplish the last requirement, the relationship of all participants and how they collaborate with each other must be visualised. Thus, the developers have a clear framework to work on. For instance, all participants know which disciplines they have to work with, which areas they should explore and which technical terms they should learn.

5.2 Creative Techniques

Due to the requirements, the researcher reviewed several literatures (Walker, Dagger and Roy, 1991; Baxter, 1995; De Bono, 2000a; De Bono, 2000b) in order to identify the creative techniques that are excellent in divergent thinking, challenging the established approaches and exploring the radical outcomes. Nevertheless, the creative methods that open up many possibilities, such as 'Brainstorming' and 'SCAMPER,' were not considered appropriate, since most solutions generated are not likely to fit the objectives or constraints set out. Moreover, the tools that rely heavily on "analogical thinking," e.g. 'Analogies' and 'Metaphors,' were not considered suitable for a complex problem like the model formulation. A clear a systematic procedure is required.

Baxter (1995), which examines a lot of creative techniques, recommends the 'Lateral Thinking' technique as a systematic method to achieve a creative breakthrough. Although other creative methods, such as 'Objective Tree' or 'Morphological Analysis', provide systematic thinking, they heavily emphasise finding practical solutions. Thus, they may prevent the researcher from exploring radical ideas, which have not been proven as useful. Besides, most creative tools considered for this research, e.g. 'Parametric analysis', were designed to reduce or expand a problem rather than investigating it from a new perspective, which is crucial for the new model development. As a result, three creative techniques are selected. Lateral Thinking (De Bono, 2000a) is selected to formulate the conceptual model due to its systematic approach and an ability to explore new angles of the problem and provide radical outcomes. The principles of the other two techniques, namely the Six Thinking Hats based on Parallel Thinking (De Bono, 2000b) and

Boundary Shifting (Walker, Dagger and Roy, 1991), are addressed in the new NPD process, since they match the requirements of Smart Clothing development.

5.2.1 Lateral Thinking

This creative technique is chosen to formulate the new conceptual model, since it specialises in changing perceptions and concepts that are firmly established. By refusing to accept that the current way is necessarily the best way, the lateral thinking technique challenges its users to explore new ways and new approaches of looking at things. After the users' minds are unlocked from the old structure, old pattern, old concept, or old perception, radical ideas can be achieved. Although, the lateral thinking technique has been proved to be useful and is widely adopted by many organisations (De Bono, 2000a), the researcher also conducted a creative session by using this creative technique to generate the new ideas for Smart Clothing application in order to find out whether it can help Smart Clothing developers overcome their existing creative boundary. One example of the ideas discovered from the creative session is demonstrated below.

> Through the use of lateral thinking technique, the key concepts that dominate the design of Smart Clothing applications are identified and then challenged. One of the dominating concepts is that *'electronic function must be invisible.'* In order to go beyond the creative boundary, a provocation is set up by reversing the dominating concept. As a result, the provocation statement is that *'every electronic function must be visible.'* This statement leads to an idea that each image on the clothes' surface represents a particular function. For example, a picture of a mobile phone on a front of a t-shirt indicates that this area locates a communicating function. The user can make a phone call by pressing the button on the mobile phone image. The more images, the more functions attached on the clothes. However, the images can be more symbolic or abstract. According to this concept, the electronic components turn into a thin sticker. A circuit board is printed on one side and the image is printed on the other. This way, the image and electronic function can be attached and removed easily from the garments. Moreover, electronics can become decorative element of the clothes.

Figure 5.1: A sample of the ideas derived from the lateral thinking technique

Through the use of lateral thinking technique, the researcher came across many feasible ideas that have not been recognised by the Smart Clothing developers. It can be assumed that this technique can break through the creative boundary and fulfil the first requirement.

5.2.2 Six Thinking Hats and Boundary Shifting

The Six Thinking Hats: The principle of the Six Thinking Hats are considered appropriate to address in the new conceptual model, since it makes the full use of multiple views of different individuals on any given topic without conflict or unnecessary argument. As the Six Thinking Hats allows the brain to think in a different direction at different time, it ensures that every aspect of the complex topic is covered. This technique is based on 'parallel thinking' which means that '*at any moment everyone is looking in the same direction'* (De Bono, 2000b). As a result, all viewpoints, no matter how contradictory, are put down in parallel providing a basis for decision-making. The 'hats' are the direction label, which indicates the role for the users. This technique has two rules. Firstly, one does not respond to what the last person has said but simply adds another idea in parallel. In this way, the argument can be minimised. Secondly, only one direction of thinking is allowed under each hat. For example, when the direction is objective facts and figures, no opinion is permitted. Another advantage of this technique is that it does not categorise people. For instance, creative thinking is not restricted to the designers. De Bono (2000b) emphasises that *'the whole point of parallel thinking is that the experience and intelligence of everyone should be used in each direction.'*

There are many similarities between the principles of the Six Thinking Hats and the requirements of Smart Clothing development projects. Therefore, the principles of this technique can be adapted, for example every participant has a chance to give some suggestions on every part of the Smart Clothes. As a result, the experience and intelligence of the electronic engineers can be addressed into the task like fashion design. Further details on how the principles of the Six Thinking Hats are embraced into the new conceptual model will be shown later in Section 5.3.4.

Boundary Shifting: The Boundary Shifting occurs when a new constraint is introduced to any given problem. The circumstance where the Boundary Shifting technique is required is similar to Smart Clothing development projects, as the applications need to break through the boundary of the conventional garments and electronic devices. Walker, Dagger and Roy (1991) assume that every design is limited by certain constraints such as materials, manufacturing process, cost and so on. Since each constraint does not operate independently, the change of one constraint leads to subsequent changes of the others. The authors explain that the boundary constructed from the constraints is laid over all possible solutions of a design problem. According to this boundary, the solutions can be categorised into three groups: 1) impossible solutions located outside the boundary, 2) exploratory and risky solutions placed close to the boundary, and 3) conventional solutions positioned at the centre. By changing some of the constraints, the design solutions once regarded as impossible can become possible (see figure 5.2).

To employ this creative technique, firstly one needs to identify fundamental constraints of a particular problem. Next, certain constraints are selected and changed in order to search for a new solution. The principle of the Boundary Shifting technique can be applied to the Smart Clothing development. Once the constraints of the conventional garment design and the electronic product design are identified, the new boundary for Smart Clothing application can be generated. As a result, the developers are able to break through their existing creative boundary. Further details on how the principles of the Boundary Shifting are addressed into the new conceptual model are presented later in the Section 5.3.4.

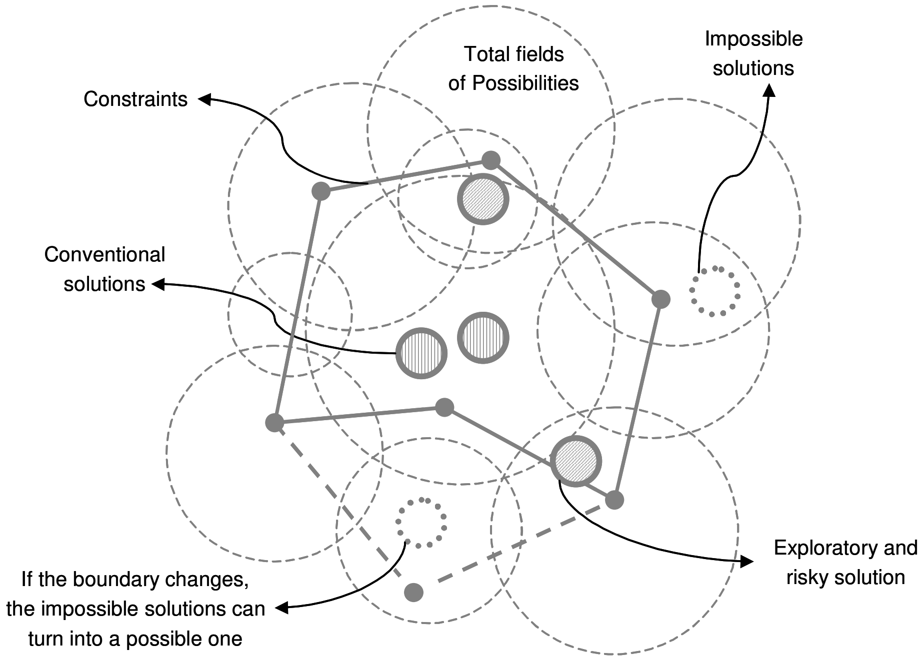

Figure 5.2: Diagram demonstrating how the change of one constraint can affect the others

5.3 Model Formulating Procedure

Based on the lateral thinking technique, this formulating procedure can be divided into four stages: 1) identify the dominating concepts, 2) analyse the dominating concepts to find out the reason of the continuity, 3) challenge the concepts that are no longer valid and develop the new alternatives, 4) evaluate the alternatives, select the most appropriate idea and implement the chosen idea. These four stages are described in detail respectively.

5.3.1 Identifying Dominating Concepts

The aspects that are shared among all NPD models are regarded as the dominating concepts. According to the comparison of the well-known NPD models presented in chapter 1 and 2, it can be concluded that there are five dominating concepts.

1. The development tasks are divided into certain stages, e.g. Stage-Gate model (Cooper, 1993). These stages represent a sequence of activities, which are carried out in order.
2. The NPD models are usually presented in a linear form, e.g. Pahl and Beitz's design process (1984), Sinha's design processes (2001), and DIT's Design Flows (2002b).
3. The NPD models provide a basic guideline or a checklist.
4. The NPD models must be general and adaptable.
5. The NPD models seldom specify which individual is responsible for which task. The exceptional samples are Matsushita Industrial's NPD process (figure 1.11), Snelson and Hart's model (1991, cited in Hart and Baker, 1994), and Ulrich and Eppinger's generic model (2000), which clearly defines responsibilities of different departments.

5.3.2 Continuity Analysis

Once the dominating concepts are identified, they are analysed by questioning 'why' several times in order to find out what are the underlying reasons of the continuity. De Bono (2000a) summarised that there are three possible reasons: 1) the concept is still the best way of doing things, 2) the benefits from change are not worth the disruption and cost of change, and 3) there has never been any need, occasion or pressure for change. If the continuity analysis indicates that the dominating concepts continue because of the third reason, these concepts can be challenged and the new alternatives should be explored to replace them. As a result, five dominating concepts are analysed as follows.

1. **The development tasks are divided into certain stages**.

- Why are the development tasks divided into certain stages?

This characteristic reflects a reality, as the research results show that the developers divide a complex task into the smaller and simpler ones before they start working.

- Why do the developers divide the development task before they start working?

This is the way the developers have been trained. Dividing the complex task into the simpler ones makes the NPD process easy to understand and execute. Since a goal of each stage can be set up, it is possible to measure the progress and assess the whole outcomes.

- Why does dividing tasks make the NPD process easy to understand and measure?

Dividing the complex task into a sequence of activities clarifies what to do step by step for all participants. Moreover, it allows the team to trace back what has been achieved.

- *Is dividing tasks into certain stages the only way to simplify the NPD process?*
- *Can NPD model be presented differently without losing the simplicity?*
- *Since all participants already knew the 'stage-gate' concept through their education, why does the new NPD model need to repeat the same concept again?*

2. **The NPD models are usually presented in a linear form**.

- Why are the NPD models presented in a linear form?

The linear structure reflects the first dominating concept, dividing development task into several stages. Furthermore, the linear structure is easy to construct and comprehend.

- *If the first concept is challenged and replaced, will the linear structure be changed?*
- *Can NPD have a different form without losing its simplicity and comprehensibility?*

3. **The NPD models provide a basic guideline or a checklist**.

- Why do the NPD models work like a basic guideline or a checklist?

Many of the NPD models aim to educate the inexperienced entrepreneurs, students, and product developers (see DTI Electronics Design Programme, 2002b for example). Therefore, these models tend to provide a basic guideline that is easy to follow. Besides, the checklist is given to double check if every critical task is included and done correctly.

- Why do the experienced product developers still employ these models?

Since the product development process is very complex, a checklist is needed to measure the progress, and ensure that every task has been assigned, all required resources have been allocated and everything is on schedule. Hence, the checklist is still relevant.

- *Does the new NPD model need to address this checklist function?*
- *As there are many NPD models that provide this function, can the new NPD model exclude this function and propose a new function that no model offers?*
- *Is it possible for the development teams to employ more than one NPD model?*

4. **The NPD models must be general and adaptable**.

- Why do the NPD models have to be general and adaptable?

This is because all theorists realised that it is impossible to make a model that fits every organisation. To overcome this problem, most theorists generate their NPD models in such way that they can be adapted to any type of the product development process.

- Why do the NPD models have to fit every organisation?

The models must be relevant to every organisation because most theorists want to make the full use of their concepts. Thus, the models should not address any specific aspects.

- *Is it possible to design a model specifically for a particular organisation/product?*
- *Can 'adaptability' and 'customisation' be presented in different way other than keeping everything simple and general?*
- *Is this idea the only way to make the full use of the NPD model?*

5. **The NPD models seldom specify which individual is responsible for which task**

- Why do the NPD models not specify which individual is responsible for which task?

This is because specifying responsibilities adds complexity to the models. As the activities in each stage are carried out in collaboration, it is difficult to identify which task is which participant's responsibility. Moreover, each organisation works differently; therefore, specifying responsibilities may limit the use of the NPD models.

- Why are some models able to specify which individual is responsible for which task while maintaining the simplicity and the adaptability?

These models do not precisely spell out which participant is responsible for which task. They tend to indicate which task is assigned to which department. In this way, the models are still simple and not restricted to certain operation or organisation. Several models make clear which task is carried out by which discipline. For example, Sinha's models state that the selection process is undertaken by the buyers or the agents (see figure 2.5).

- *Is it possible to specify precisely which discipline is responsible for which task without complicating the models and confusing the developers?*

The results of the continuity analysis indicate that these dominating concepts are not necessarily the best way to present the NPD conceptual models. The analysis suggests that some functions and concepts are still valid and relevant. For instance, the checklist function is useful for both inexperienced and experienced developers. Nevertheless, there is no need to include the same functions or repeat the conventional concepts known by all participants in the new conceptual model. Based on the interviews results, all participants already employed the existing NPD models. Therefore, there is an opportunity to introduce the new functions and new concepts to solve the problems that the teams encounter when developing Smart Clothing applications, e.g. clarifying the responsibility and contribution of each participant. However, this new model must address certain characteristics shared by all existing models, such as simplicity, adaptability and comprehensibility, since they are the basic requirement of all the NPD models.

5.3.3 Challenging Invalid Concepts

There are three methods to challenge the invalid concepts and ideas, and develop new alternatives. These methods are the concept fan, the provocation and the random input.

The Concept Fan: To escape from ideas or concepts that are no longer valid, the underlying approaches must be identified so that the alternative ways to carry out these approaches can be developed. De Bono (2000a) introduces the 'concept fan' to track back the underlying approaches of any given idea. The concept fan consists of three key levels. The 'idea', which means a specific concrete way of putting a concept into work, is at the lowest level. At the second level locates the 'concept', which is a general method or way of doing something. Finally, at the highest level situates the 'direction', which is a very broad concept or approach. Using a problem of attaching something to the ceiling as an example, *using a ladder* is regarded as an 'idea'. *Raising a person above the ground* becomes a 'concept' and lastly *reducing the distance between the object and the ceiling* is considered as a 'direction.' With the concept fan, each level turns into a 'fix point' for the alternatives. Using the concept fan method, the dominating concepts of the generic NPD models are challenged and the alternatives are generated (see figure 5.3). The new alternatives leads to a concept of specifying the responsibilities and the contributions of all participants involved instead of dividing the development tasks into certain stages.

Using a bubble diagram as an example, each bubble represents a responsibility, a contribution or a specific discipline rather than an activity (see figure 5.4).

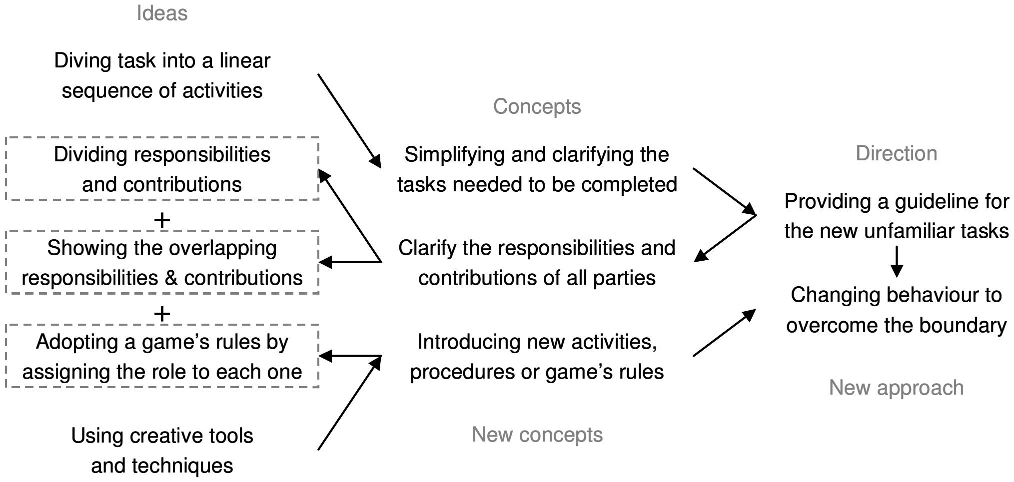

Figure 5.3: The concept fan demonstrating alternative ideas for the new NPD model

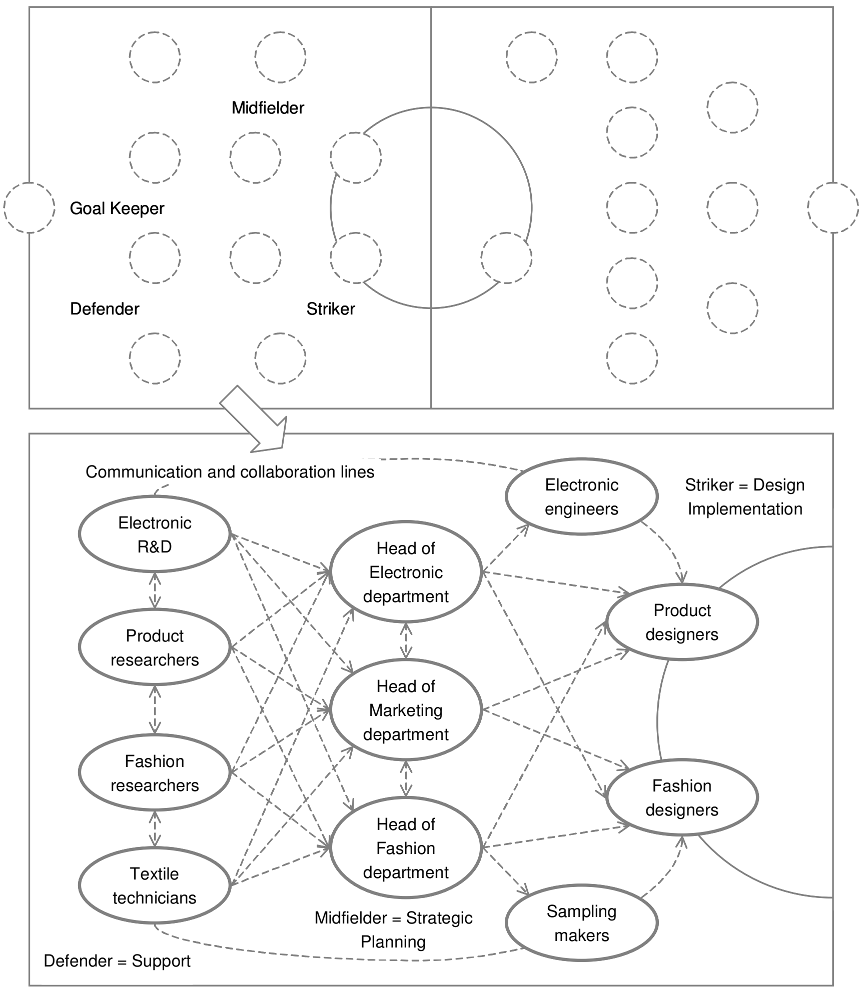

Figure 5.4: Bubble diagram presenting a rough idea derived from the concept fan

All bubbles can be overlapped in order to illustrate the overlapping of responsibilities and contributions. Since the concept of game playing is applied, the location of each bubble indicates the role in the same way that the position of the player on the pitch does (see figure 5.4). The participants designated the same role share the responsibilities and contributions. As a result, these participants must work in collaboration and frequently communicate. However, this concept requires a further development and will be combined with the ideas generated from other techniques.

Provocation: The second method to challenge the invalid concepts is the 'provocation.' De Bono (2000a) defines this term as *'with a provocation there may not be a reason for saying something until after it has been said. The purpose of the provocation is precisely to get us out of the usual main track of thinking.'* As a result, the provocation seems illogical, contradictory and impossible within the existing pattern of information systems. The word 'Po' (provocation operation) is introduced to signify the provocation statement. This technique contains two stages: setting up the provocation and using the provocation.

Setting up the provocation: There are two methods to set up the provocation.

1. **The escape method**: This method consists of two steps: 1) spelling out the take-for-granted features of any given subject, and then 2) escaping from these features. Using a restaurant as an example, the take-for-granted feature is that 'restaurants have food.' Hence, the provocation statement will be 'Po, restaurants do not have food.' This leads to an idea that people bring their own food when going to the restaurant. As a result, the restaurants become an elegant place for indoor picnic (De Bono, 2000a). The examples of the provocation statements using this method are shown below.
    - The development tasks are carried out in a specific order

Po, the development tasks have no order

- The development process is divided into certain stages

  Po, the development process contains no stages

- The participants come from different areas

  Po, the participants come from the same field

2. **The stepping stone method**: There are four techniques included in this method.

2.1 The first technique, *reversal*, identifies the usual direction in which something is done and then going in the reverse or opposite direction. The samples of provocation statements using this technique are presented as following.

- The developers use NPD models as a guideline

  Po, NPD models use the developers as a guideline

- Dividing tasks simplifies the NPD process

  Po, NPD process simplifies the task of dividing

2.2 The second technique is *exaggeration*, which is related to the dimension or measurement such as number, frequency, volume, temperature, duration, and so on. Exaggeration suggests a measurement that is far outside the normal range. The exaggerated range can be obtained by increasing or diminishing the normal one.

- The NPD models normally comprises five to six stages.

  Po, the NPD models have only one stage

  Po, the NPD models have one hundred stages

- The NPD process requires four key disciplines, namely designers, marketers, engineers and manufacturing staffs.

  Po, the NPD process requires only one discipline

  Po, the NPD process requires at least fifty different disciplines

- One task is carried out by several participants

  Po, one task is carried out by one participant

  Po, one task is carried out by all participants

2.3 The third technique is *distortion*. This technique is based on the assumption that any situation has the normal time sequences of the action and the normal relationships between parties. Therefore, the provocation statement can be gained by changing the normal arrangement into the new one. The examples are:

- The process starts with researching, designing, producing and then selling.

  Po, the process starts with selling, producing, designing and then researching

- The process is planned before being executed.

  Po, the process is executed before being planned

- All tasks are carried out separately and assembled together at the end

  Po, all tasks are assembled together before carrying out separately

2.4 The last technique is *wishful thinking*. De Bono (2000a) describes this technique as *'we put forward a fantasy wish knowing that it is impossible to achieve. It is much too weak just to put forward a normal desire, objective or task.'*

- The developers have to alter the NPD model to fit their specific requirements

  Po, it would be ideal if the NPD model adapts or rearranges itself automatically for every development team according the different needs

- The conceptual models are usually simpler than the real processes

  Po, it would be ideal if the real process is as simple as the models.

Using the provocation: The key activity is 'movement' which focuses mainly on moving forward from a provocation to a useful new idea or concept rather than justifying whether the statement is right or wrong. There are five techniques included in the movement.

1. **Extract a principle**: This technique aims to extract a principle or a concept from the provocation and then build a usable idea around it. It ignores the rest of the provocation and concentrates only on the principle that has been extracted.
2. **Focus on the difference**: This technique focuses on contrasting the provocation statement to the existing idea or the current way of doing things in order to spell out the differences, which may lead to an interesting new idea.
3. **Moment to moment**: This technique requires the user to imagine that the provocation is put in effect. After the provocation is visualised, the user is able to observe the moment-to-moment happenings and then build the ideas from them.
4. **Positive aspects**: This technique seeks for the direct benefits or positive aspects in the provocation. It is interested in the value immediately presented rather than what the provocation may lead to. The new ideas are built around the value taken.
5. **Circumstance**: This technique searches for the circumstance that would give a value to the provocation. The new ideas are developed based on this circumstance.

Certain provocation statements and some of the movement techniques are selected and employed in order to develop the new ideas. Four ideas generated from the provocation method are presented as follows. Nevertheless, they require further development and must be combined with other ideas created from the other two techniques.

Po, the process starts with selling, producing, designing and then researching According to the *'focus on the difference'* method, the key difference is that the product is already purchased before it has been designed and produced. This triggers an idea of providing many basic components rather than one final product. As a result, the users can design and assemble the components that they bought by themselves. Another idea is to sell the product ideas to the potential customers, and then produce them due to the orders.

Using the *'moment to moment'* method, it can be visualised that the developers know the end result before they start the process. This initiates an idea that all participants must work together until every part of the design is clarified and satisfies everyone. Then, the developers can move on to work on their parts separately. This idea also answers another provocation statement: Po, all tasks are assembled together before carrying out separately.

Po, NPD models use the developers as a guideline

The first method, *'extract a principle'*, is employed to move from this provocation. The principle extracted from this statement is that the NPD model must follow the developers. Generally, the key components in the NPD models, approximately five or six aspects, represent the major tasks. However, based on this principle, the components of the NPD model should signify the key participants instead of the major tasks. Consequently, the number of the components is the number of the participants involved. Furthermore, the relationships between the components illustrate the relationships of the participants.

Po, the development process contains no stage

The *'moment to moment'* method is employed. The researcher visualises that there is no layer between any tasks. Imagining all tasks are laid down on a flat surface, they are linked together like a piece of jigsaws. Correlated tasks are placed next to each other. This observation suggests a new idea of presenting the NPD conceptual model that is displaying every task in parallel and linking related tasks like the pieces of jigsaws. Since the tasks are grouped, they can be assigned to a particular discipline or department. This idea may promote 'concurrent engineering', as every task is carried out simultaneously.

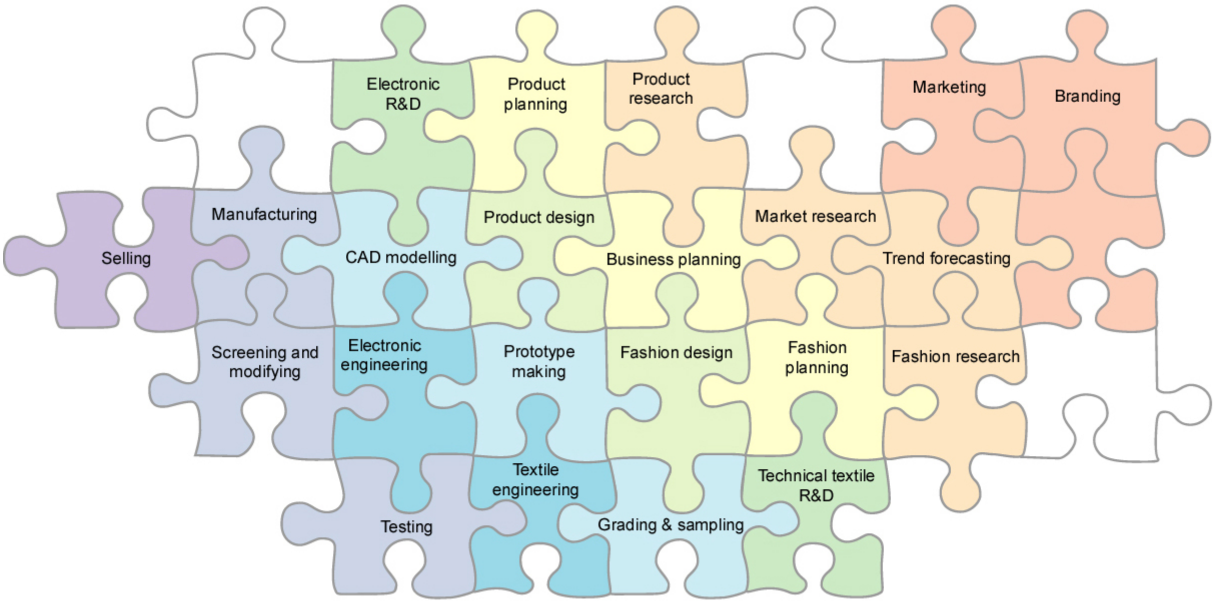

Figure 5.5: Diagram demonstrating an idea derived from the provocation statement

Po, it would be ideal if the NPD model adapts or rearranges itself automatically Using the *'extract a principle'* technique, the principle of a self-configuration is extracted and applied. The concept of self-configuration according to the user's specific needs is similar to a characteristic of a neural network system within computer software. This system learns and memorises how the user works. Consequently, it helps the computer software behave in the way that the user wants. This leads to an idea of having the NPD model in an electronic version. After the developers fill their specific requirements, the configuration of the NPD model's components can be rearranged to match their needs.

The Random Input: The third technique employed to develop a new idea is the random input. According to De Bono (2000a), this method seeks the way out off the main track by starting at a new point. Firstly, a word that has no connection with the situation is selected randomly. Next, an attempt is placed on making a connection between this word and the focus area. As a result, the chance of hitting the new track is increased. However, if the random word is closely connected to the situation, there is a little provocative effect. In this case, the random word is 'pistol.' The new ideas developed from this method are:

1. The first characteristic of the pistol is that it is a product comprising of several parts. Each part serves different function. Once all components are joined together, the pistol can fire a bullet at the target. This characteristic is very similar to the product development team. The combination of the different disciplines produces a product that hits the target or achieves the goal of the project. This characteristic leads an idea of describing each participant in the development team as a part of the pistol. For instance, a trigger can be used as a symbol signifying a participant who is responsible to initiate a new idea. This way, it is perhaps easier for the developers to understand their roles and the contributions required.
2. The second characteristic is dark and dangerous. Therefore, most people, especially women, are scared of the pistol and do not want to associate with this product. To overcome this problem, a number of guns are designed specially for female targets. Consequently, they have lightweight, small size and sleek body. Comparing to the NPD models, many people in the industries view the conceptual models as a theoretical idea, which is difficult to apply in practice. As a result, the new conceptual model should have an attractive presentation in order to change the perception and pursue the developers in the industries to employ it. Furthermore, some humour may be added to make it more pleasurable to use.
3. The third characteristic comes from the target rather than the pistol itself. The

target is divided into several areas with different scores; thus, the points that the bullets hit determine the total scores. This principle can be applied to the goal of all the disciplines. Instead of specifying definite outcomes required from each participant, suggesting the area or the boundary he/she could work on increases the chance of exploring new ideas and new procedures. Nevertheless, the goal and the methods, which each developer chooses, determine the total performance of the product. The given scores should cover both aesthetics and functionality.

To conclude, there are nine ideas developed through the use of the lateral thinking technique (see table 5.1). These ideas will be evaluated, selected and combined in the next stage of the procedure in order to formulate the final conceptual model.

Table 5.1: The new ideas developed through the use of lateral thinking method

Techniques	**Ideas**
The concept fan	1. A combination of a bubble diagram representing the different responsibilities contributions and disciplines, and a concept of game playing (see figure 5.4)
The provocation	2. The self-configuration concept lets the developers input their specific requirements, and then adjusts the key components of the model accordingly to fit the particular needs. 3. All tasks are presented in parallel and linked in the structure of a jigsaw in order to clarify the relationship between each task and the responsibilities of all disciplines involved (see figure 5.6). Thus, the whole picture of the development team can be seen. 4. The development tasks can be simplified and reduced by allowing the users to design and assemble their own product using the basic components provided by the producers. 5. All parts should be designed together in order to ensure the satisfaction of the whole team before each team member can move on to complete their works separately. 6. The conceptual model is designed based on the developers. As it reflects the structure and the relationship of the development team, it provides a clear framework to work on.
The random input	7. The roles of the participants in the development team are described as the components or the mechanism of the product. This way, the developers have a clear picture of how they work together as a team and how their works affect the others and the final result. 8. Make the conceptual model more interesting, attractive and fun to use by the developers.

Techniques	Ideas
The random input	9. Provide the boundaries for each team member to work on instead of defining the precise outcome required from each discipline so that they has chance to explore the new ideas.

5.3.4 Evaluate and Implement New Ideas

In this section, the new ideas generated earlier will be evaluated, selected and combined. The criterion is that the ideas must fulfil the requirements of the conceptual model and promote the principles of the Six Thinking Hats and the Boundary Shifting. Since none of the ideas is able to meet every requirement, it is important that the selected ideas must be compatible with the others. The results of the evaluation are:

- Idea no.1 (of the table 5.1) is appropriate for the new conceptual model. Firstly, the structure of the bubble diagram supports the principle of the Boundary Shifting technique (see figure 5.2), since it can show all the responsibilities and contributions and how to expand them. In this way, the first requirement can be fulfilled. Secondly, the idea of role playing or game playing fits the concept of the Six Thinking Hats. Thirdly, the responsibilities and contributions of each participant or discipline are clarified. Nevertheless, this idea is unable to depict the context of Smart Clothing development clearly. As a result, it requires other ideas to support on this issue.
- Idea no. 2 alone cannot fulfil any requirement. However, it supports and strengthens other ideas. By allowing the developers to input their specific needs and information about their teams, the NPD model becomes easier to alter and adapt, as the developers do not have to figure out how to employ the conceptual model themselves.
- Idea no. 3 shares some similarities with the idea no. 1, since all responsibilities and contributions are laid down in parallel. However, the arrangements and the linkages are different. This idea answers the requirements no. 2 and 3, as it clarifies all the

responsibilities and the relationships between all participants as well as portrays the context of Smart Clothing development. Nonetheless, it does not promote the principles of both the Six Thinking Hats and the Boundary Shifting. It is possible to combine the idea no.1 and the idea no. 3. This way, the new conceptual model can promote the principles of both creative techniques and meet all three requirements.

- Idea no. 4 is not exactly related to the new conceptual NPD model. Nevertheless, it suggests a new way of producing and commercialising Smart Clothing applications. This idea will be kept for the recommendation in the following chapter.
- Idea no. 5 does not actually associate with the conceptual model formulation. However, it proposes the alternative method for the developers to develop their products and reduce the conflicts occurred from miscommunication. As with the previous one, this idea will be retained for the recommendation in the next chapter.
- Idea no. 6 is similar to the idea no. 3, as it focuses on the relationships between the participants and the overview of the Smart Clothing development process. Thus, it shares the same pros and cons. As a result, it is possible to merge these two ideas.
- Idea no. 7 is similar to the idea no. 1. Nonetheless, the principles are rather different. While idea no. 1 applies the principle of game playing to describe the different roles of the participants, idea no. 7 use the principle of the product’s mechanism to explain the relationships between all developers. Which principle is selected is based on its compatibility with the other ideas, as all ideas must be combined together.
- Idea no. 8 cannot accomplish any requirement similar to idea no. 2. However, it supports and strengthens other ideas. Moreover, the humour and fun activities can persuade the developers to try the new model and change their behaviours. For example, the respondent in the focus group stated that in the process of getting accustomed to the

fashion area, which was an entirely new area for her, fun activities like visiting fashion shops, seeing fashion shows and reading fashion magazines motivated and helped her get used to the new area quicker than reading fashion journals or fashion theories.

- Idea no. 9 supports the idea no. 1 and the principle of Boundary Shifting, since it spells out the boundaries of the responsibility and demonstrates how these boundaries can be expanded. Consequently, it fulfils the first two requirements.

Due to the evaluation, the key ideas are number 1, 3 and 7. These three ideas will be regarded as a basic concept to start with. The ideas no. 2 and 8 will be applied wherever it is possible, as they strengthen the key concepts and make the conceptual model more attractive and easier to employ. The ideas no. 6 and 9 are similar to the key concepts. Therefore, they will be used to support the main ideas. The idea no. 3 is used as a starting point, since it has the key property that none of the other ideas has – that is the ability to portray the context of the Smart Clothing development process and the development team.

Firstly, the rough idea shown in figure 5.5 is revised based on the results of the results of the research. The related tasks are placed adjacent to each other as shown in Figure 5.6. For instance, fashion design requires the information from the fashion research, R&D and strategic planning; therefore, these related tasks were positioned next to each other. Moreover, the tasks that require both electronic inputs and fashion inputs were placed in the middle, such as prototyping and testing. The diagram is analysed in order to identify the key components. Subsequently, the structure of the Smart Clothing development process is discovered (figure 5.7). According to the analysis, it can be seen that the Smart Clothing development process consists of four key elements: 1) research, 2) fashion input,

3) electronic input, and 4) strategic plan which covers three key areas, namely product design, fashion design and business. These elements are overlapped as illustrated below.

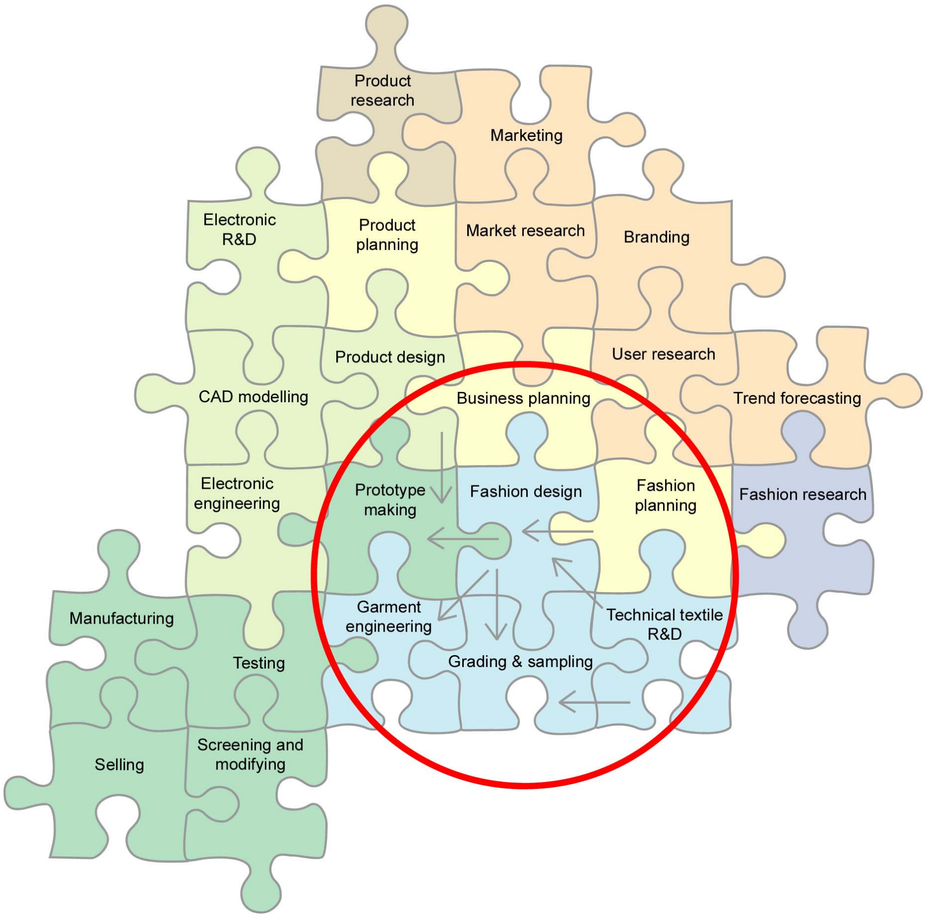

Figure 5.6: Diagram demonstrating the relationships between all development tasks

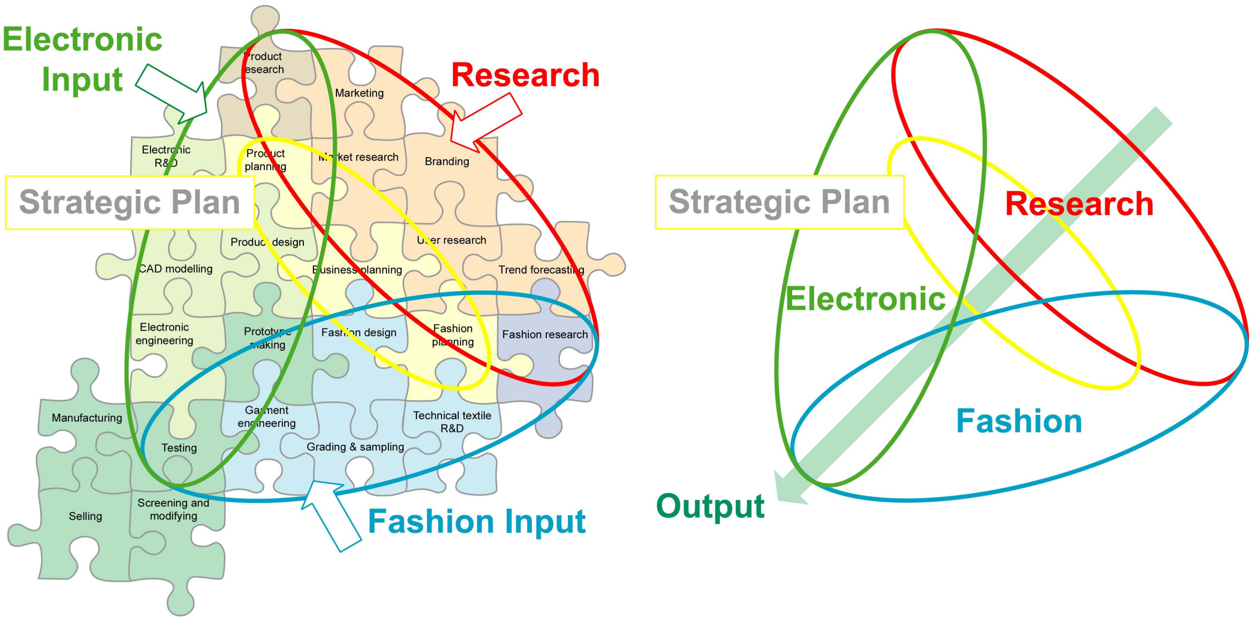

Figure 5.7: The structure of Smart Clothing development process is identified.

After the structure is identified, the next stage is to specify the position of all participants and their roles. As a result, the concept of the idea no. 1 is applied (see figure 5.8).

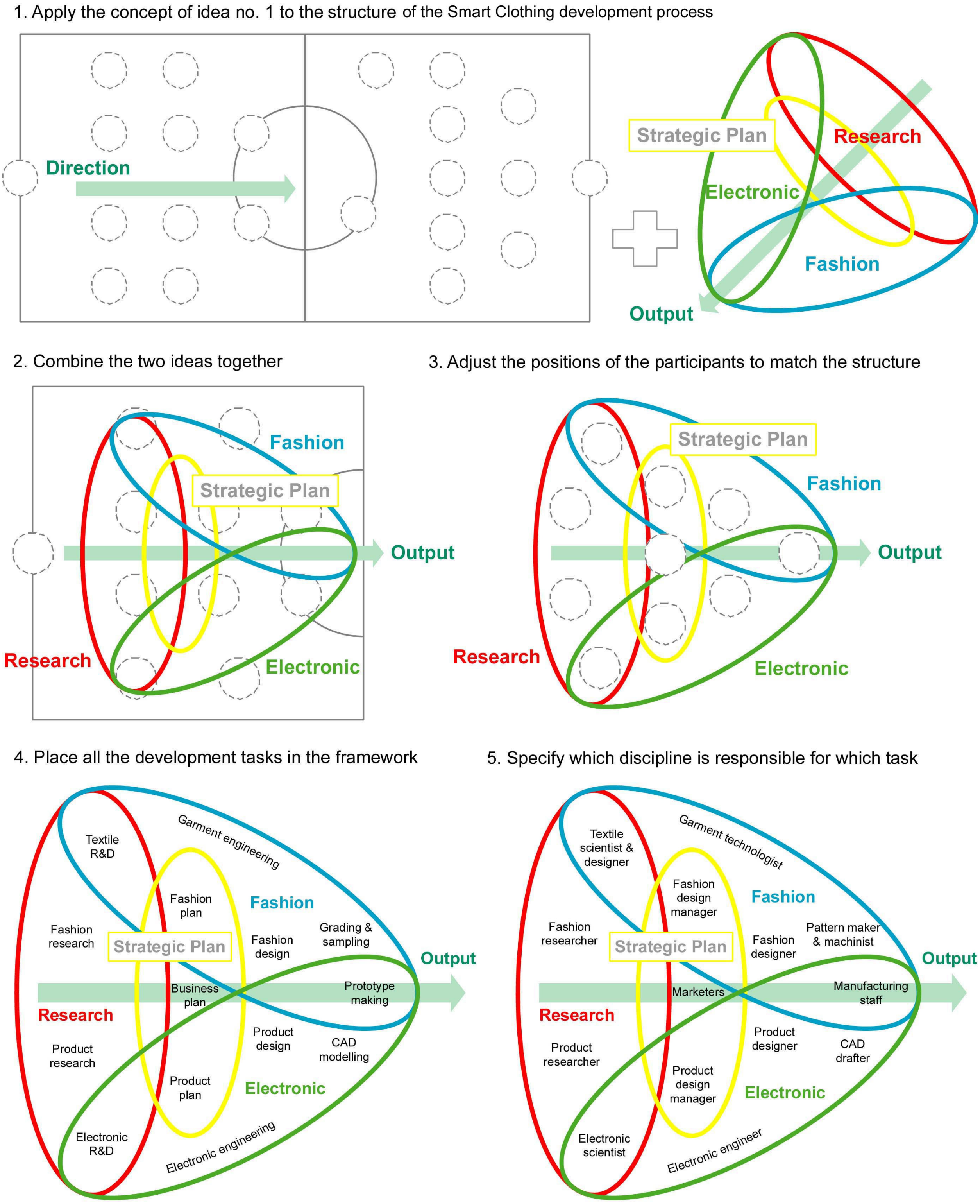

Figure 5.8: Positioning the participants into the Smart Clothing development structure

At the end of this stage, the relationships of all the development tasks are clarified and which discipline is responsible for which task is clearly described. Consequently, all participants are able to see which disciplines they have to work with and how all the tasks fit together. To avoid confusion, the structure of the Smart Clothing development process combining with the positioning of the participants and all development tasks will be called a '*framework*'. At present, the framework can be considered as a 'generic' model, as it is constructed based on the information collected from various sources. Hence, this framework is not customised specifically for any Smart Clothing development team yet.

Nevertheless, it is important to allow this framework to be personalised by each development team. This is where the concept from the idea no. 2 comes in. Idea no. 2 suggests that the model should respond, rearrange or re-configure according to the specific requirements input by the developers. Based on this concept, it leads to an idea of providing a basic framework, which any development team can fill their specific data about the tasks and the participants in (see figure 5.9). This feature perhaps helps all the partners plan their collaborative projects together in the early stage. In this manner, the framework can be used as part of a ground rule or a basis for the collaboration.

To make the framework easy to understand and follow, the relationships between all tasks and the relationships between all participants presented in the framework should reflect the reality. At this point, the concept from the idea no. 6 can be applied. Therefore, the real number of the tasks and the participants will be displayed in the framework. For example, if the team contains nine different disciplines, their names, their roles and their responsibilities should be precisely exhibited in the framework (see figure 5.9). In many cases, one discipline is responsible for more than one task or one task is carried out by two disciplines. This specific information should be presented in the framework as well.

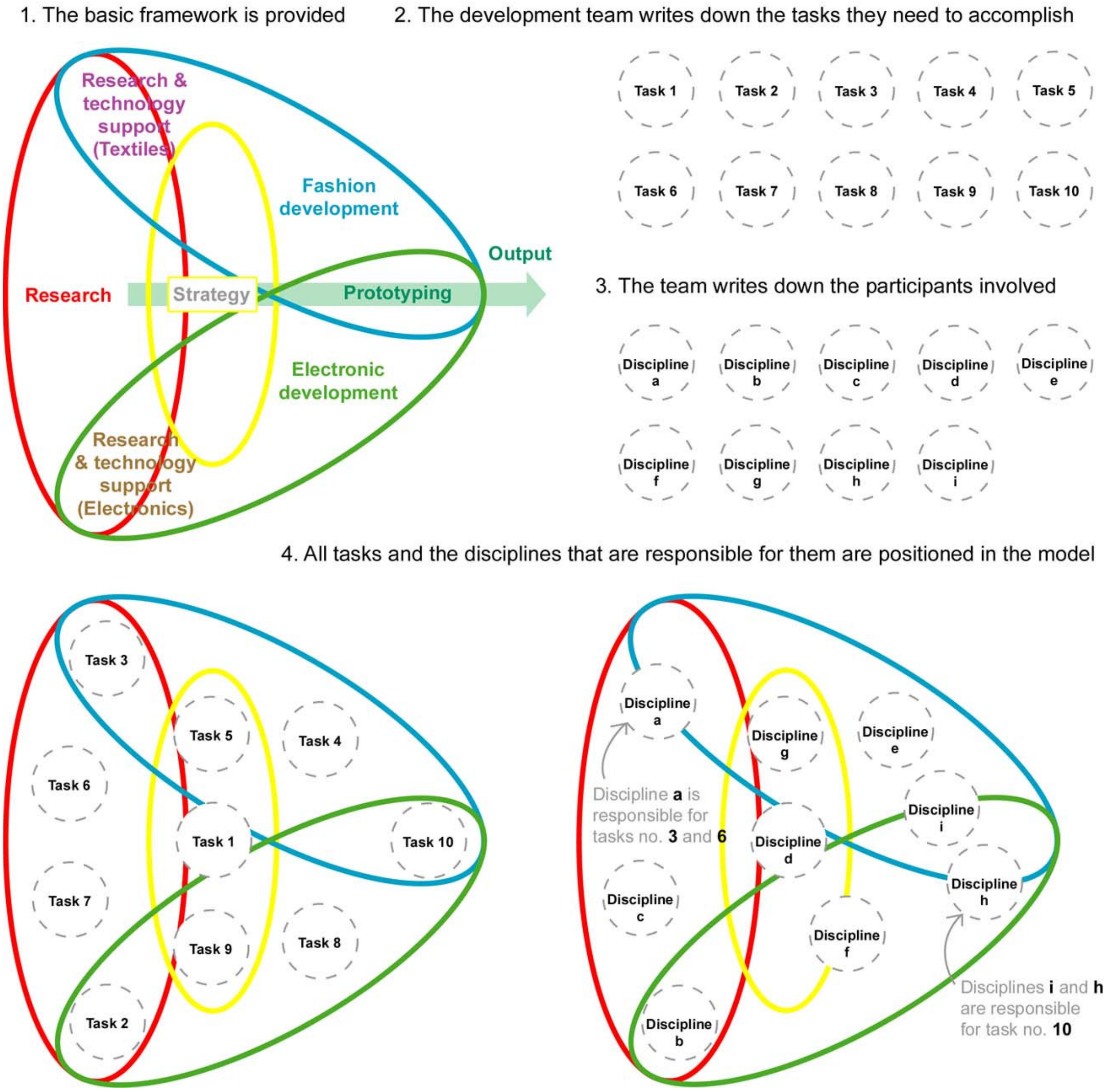

Figure 5.9: Diagram demonstrating how the framework can be customised

After the positions of all the tasks and participants are specified, the relationships between the tasks and participants can be constructed to form a basic boundary (see figure 5.10). In this way, it is clear for every participant what he/she has to deliver and whom he/she has to collaborate with. Nevertheless, this conceptual model aims not only to clarify the roles and responsibilities of all the participants but also encourage them to go beyond their creative boundary. Going beyond the creative boundary, in this case, means explore the way other disciplines think and work, and address the key issues of other areas. The closely related area or the area that requires high level of collaboration with other disciplines is probably an appropriate place to extend the creative boundary to.

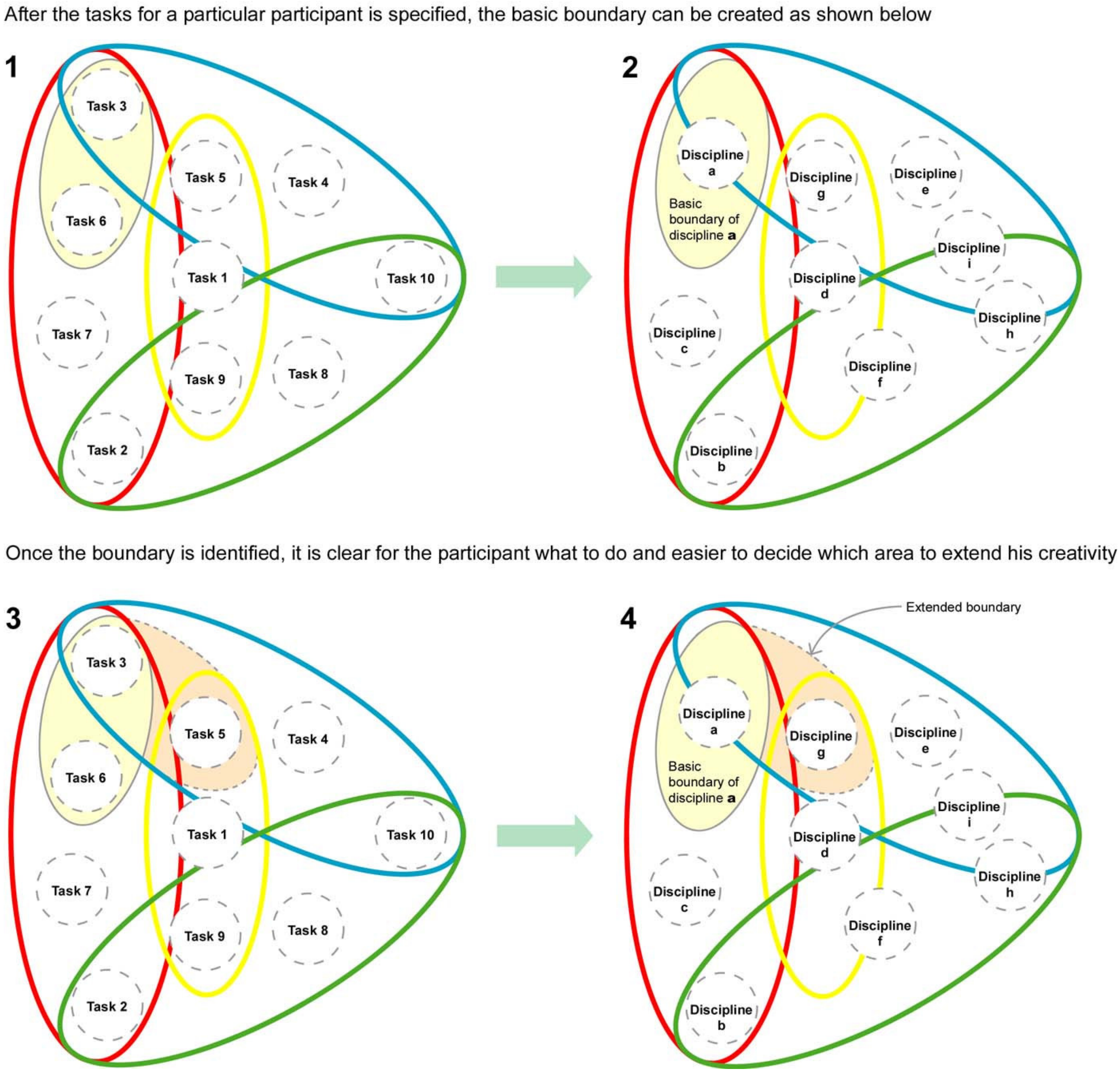

Figure 5.10: Diagram demonstrating how the boundary can be constructed and extended

Another area that the participants might consider suitable to extend their creative boundaries to is the one strongly influenced by their works. For instance, a circuit board has a strong effect on the design of the garment that accommodates it; thus, the electronic engineer should address certain issues of the fashion design in order to make the result more integrated and avoid disrupting the functions of the clothes, e.g. providing comfort.

This basic framework was presented to several researchers with different backgrounds, such as product design, computing, chemical engineering and material engineering. According to their peer reviews, most of them pointed out that the product developers in the industries prefer to alter some parts of the detailed framework rather than adopt the generic model, which is too basic and requires a lot of effort to make it specific. As a result, this framework should work at two levels. At the highest level, the basic framework was employed in order to show the holistic view of the Smart Clothing development process and roughly identify the responsibilities and the contributions of all partners. At the lowest level, all the relevant tasks are provided in order to clarify all the works that each individual has to carry out (see figure 5.11). Since the tasks are varied according to the teams and the applications the teams produce, the participants should be able to remove irrelevant tasks, add necessary tasks and combine small tasks together as appropriate. In this way, the developers spend less time to alter the conceptual framework.

The result of the peer reviews also indicates that the positions and the responsibilities of each participant may be changed through time. Therefore, the timeframe should be addressed within this framework. As adding many elements can create confusion, the best way is to revise the framework throughout the development process. Moreover, it can be employed in conjunction with the existing NPD models (see figure 5.12). For example, role and responsibility of participant 'A' change due to the different stages (see figure 5.12).

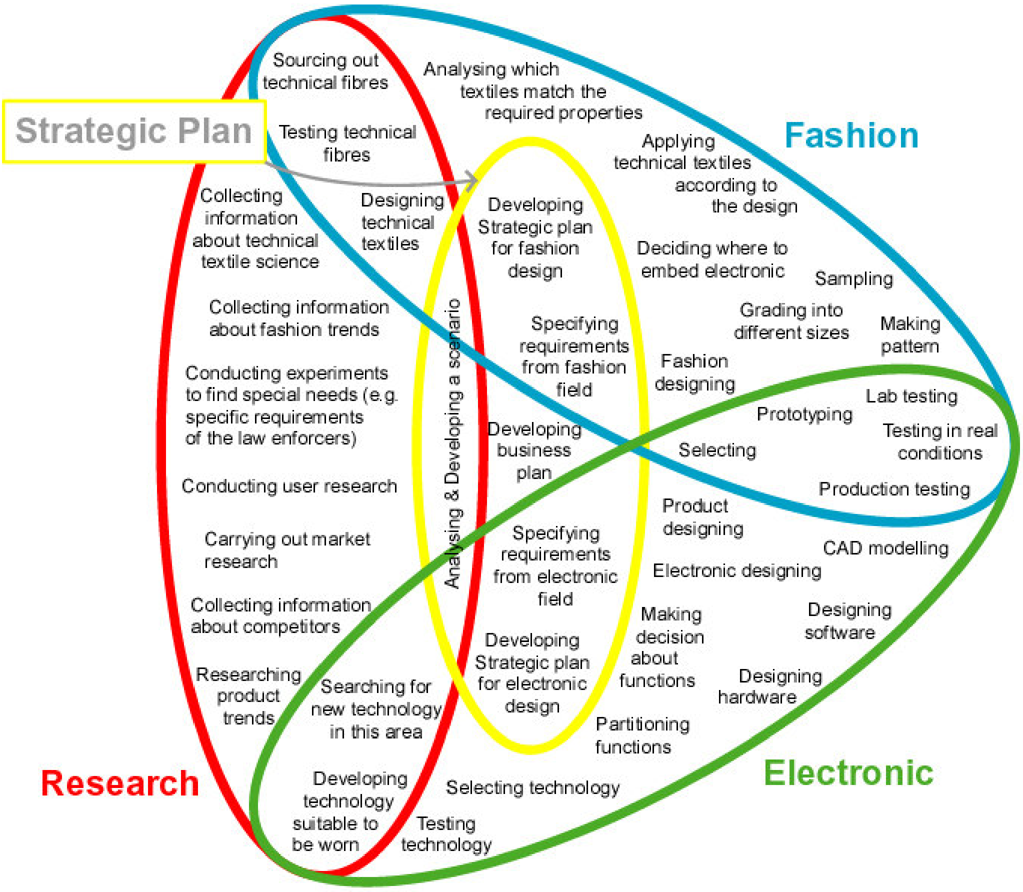

Figure 5.11: Framework presenting all tasks in details, which can be altered

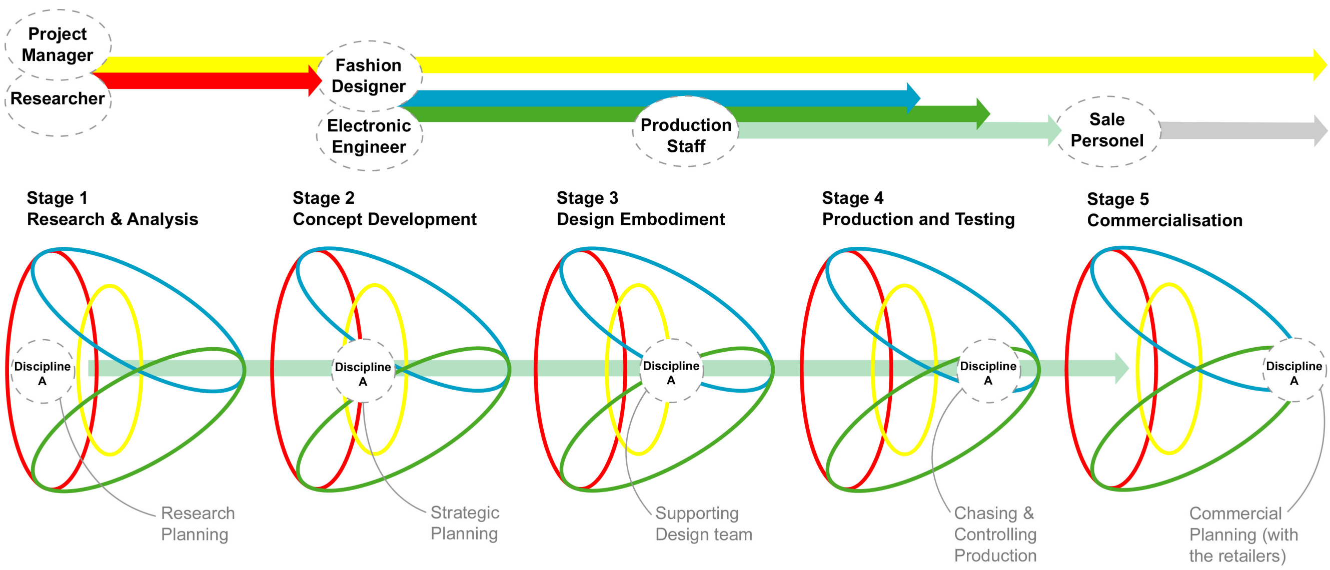

Figure 5.12: The framework being revised and combined with the generic models

The participants continue to change throughout the process. Some disciplines must be involved all the time (e.g. project manager), whilst some only need to be involved at certain stages (e.g. engineer). The details within the framework should be revised through time as same as the roles of the participants. As this research focuses on the front-end of the NPD process, the framework will present only the activities in first four stages (see figure 5.13).

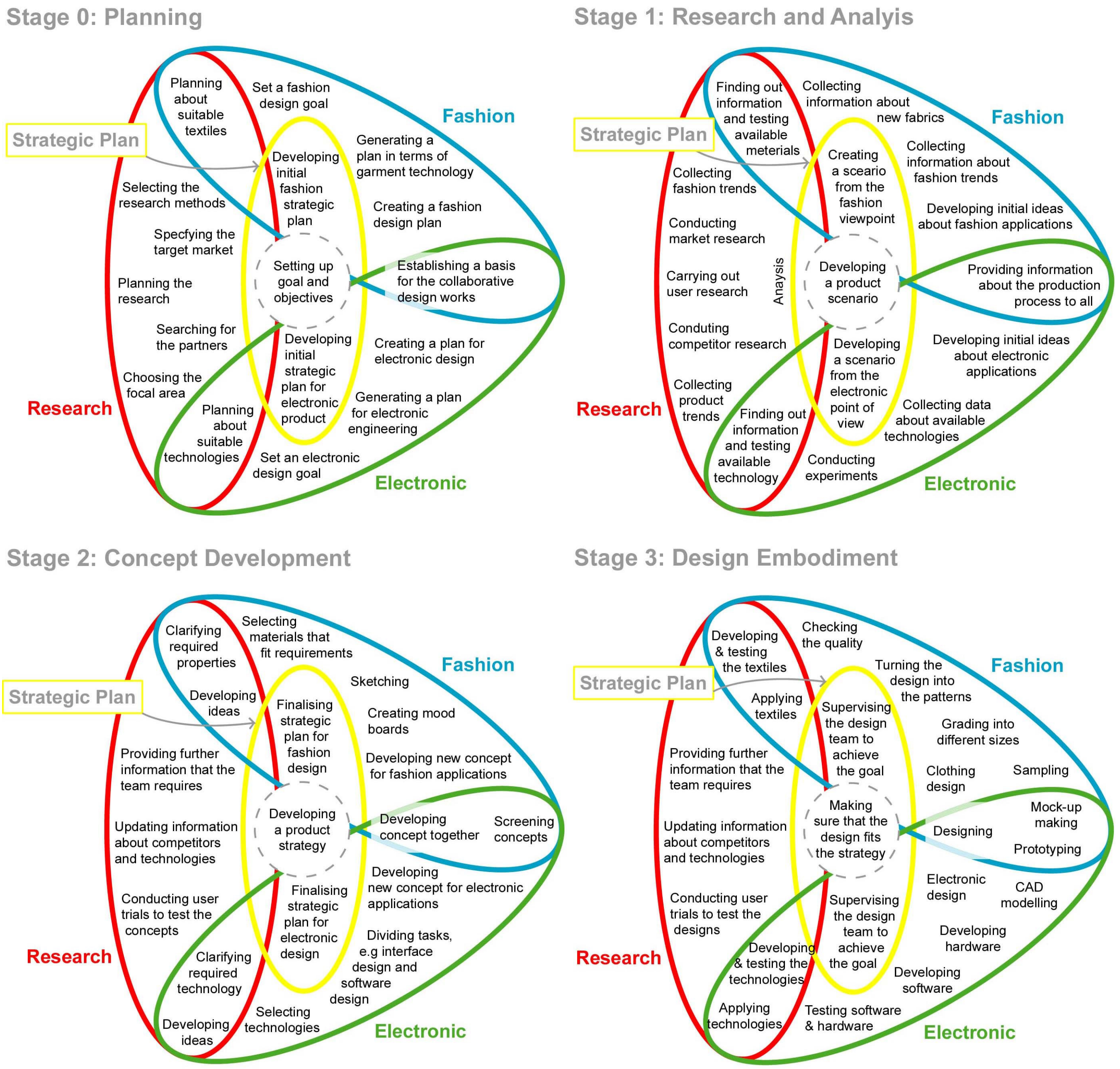

Figure 5.13: Details within the framework is revised throughout the NPD process

At this stage, the visual framework of the conceptual model is complete. The next stage is to describe the framework verbally. There are two ways of expressing the relationship between the participants. Firstly, the concept of sport or game playing can be applied (see idea no.1). Using football as a metaphor, the positions of the participants indicate the roles in the team. The strategic planners or the product champion are given the role of the midfielder, as they control the 'game.' The product champion directs, supports and helps the designers, the engineers and manufacturing staffs (the strikers) implement the design. At the same time, this person also works closely with technicians and researchers (the defenders) to prevent failures caused by the insufficient knowledge, technological problems and pass new information to the designers, the engineers and manufacturing staffs. This metaphor is useful only if all the participants understand the game's rules. If the participants do not know the game very well this idea will cause trouble rather than helping, since the participants have to learn the rules of the game before they can understand their roles in the team. As a result, this idea may have some limitation.

The second concept, using mechanism of a product to explain the relationships of all tasks and all participants, also has the same limitation. This is because most people do not understand how a particular product, such as a pistol, works. This leads to the same problem as the first idea – that is the participants need to learn how a particular product works before they can understand the whole concept of the framework. Subsequently, the effort to employ to NPD model becomes double. Nonetheless, if the chosen product is a 'representative' of the Smart Clothing application, it may strengthen the understanding about the Smart Clothing's context. However, as Smart Clothes are considered to be relatively new, it is difficult to find out the representative application with which everyone in this field agrees. Thus, until the representative application is identified, the best way to describe the framework is translating the visual form directly into words, for example:

Based on figure 5.10, 'A' or a technical textile technician is responsible for task 3 and 6 which are collecting available conductive textiles and conducting experiments to test their conductive property. He also has to collaborate closely with C, D and G (or the fashion researcher, the marketeer that is carrying out the user research and the group leader of the fashion team). He decides to extend his creative boundary into strategic planning. This means he helps the group leader plan the strategy and also address strategic issues into his R&D work, such as suggesting new useful functions based on the results of the experiments.

The concept of the Six Thinking Hats, which encourages each participant to think in the different directions at the different times, is applied every time the boundary is expanded to the new area. This is because 'going beyond the creative boundary' in this case means not only extending the responsibilities but also exploring the way of thinking and working employed in the new area. When entering the new area, the participant should think and work with the new frame of mind, which is required within that area. For instance, when moving toward the research area, the participant should concentrate on objective facts and the figures and eliminate personal opinions, which can cause bias in the research results.

The concepts of different directions of thinking can be applied as shown in figure 5.14. Although in some areas only one direction is displayed, it does not mean that the other directions are not needed. This is merely to emphasise that this type of thinking is the most important in these areas. However, this figure is only an example. In practice, the direction of thinking must be based on the disciplines working in that area. For example, when the technicians extend their works into the design area, they should prepare to think with the designer's frame of mind. In this way, the intellectual knowledge and experiences of the technicians can be used in a creative way.

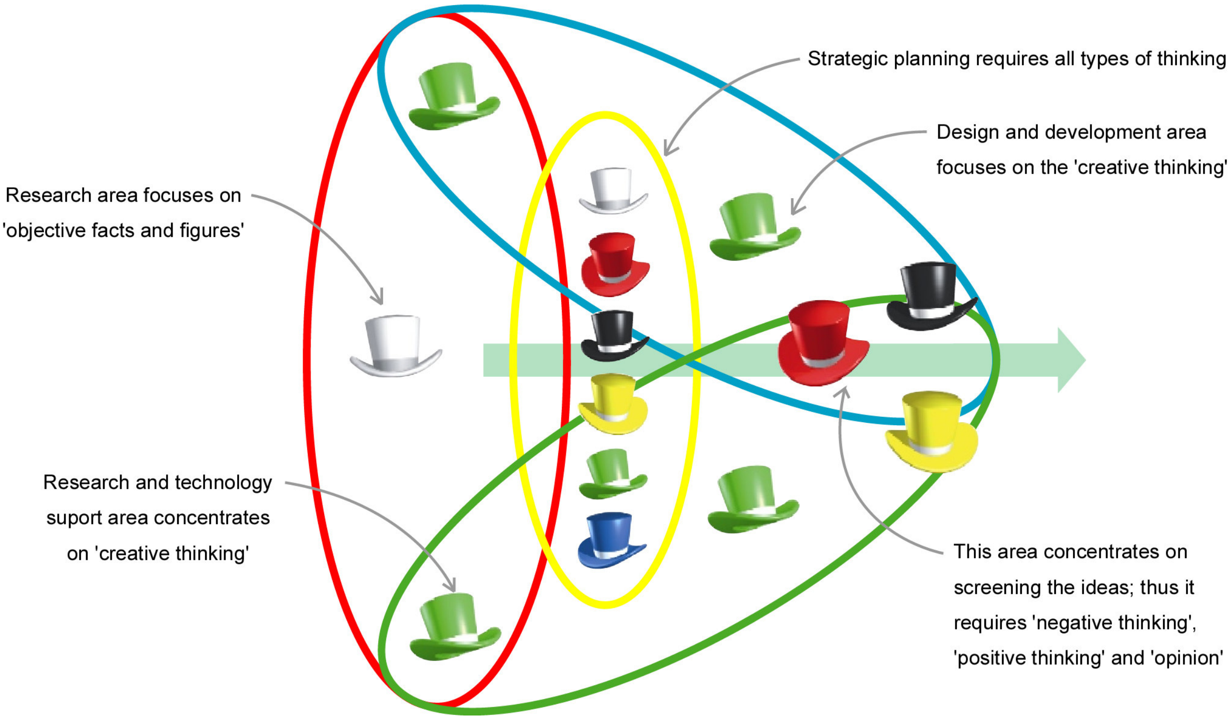

Figure 5.14: Different directions on thinking required in the different areas

5.4 Conceptual model and implementation

The new conceptual model comprises of two major parts: visual framework and verbal description. Both visual framework and verbal description work in two levels. At the highest level, the framework provides only a basic structure, which Smart Clothing collaborative teams can fill in the relevant tasks and the participants involved as appropriate (see figure 5.9). Nevertheless, the tasks specified at this stage are only general tasks without any details, such as fashion design. This framework is suitable for the planning stages, as it helps all partners establish the basis or a ground rule for the collaboration. After the data is filled in the framework, every partner will know which group is responsible for which tasks and what is the contribution of each group.

Ideally, this conceptual model should be provided in the electronic form. This way, the developers only input the information about the job titles and the expertises, and then the computer program will analyse and position each participant in the framework automatically (see figure 5.15). As with the development tasks, after the strategic planners or the product champion enter all the tasks' titles and their descriptions, all development tasks should be positioned in the framework automatically (see figure 5.15).

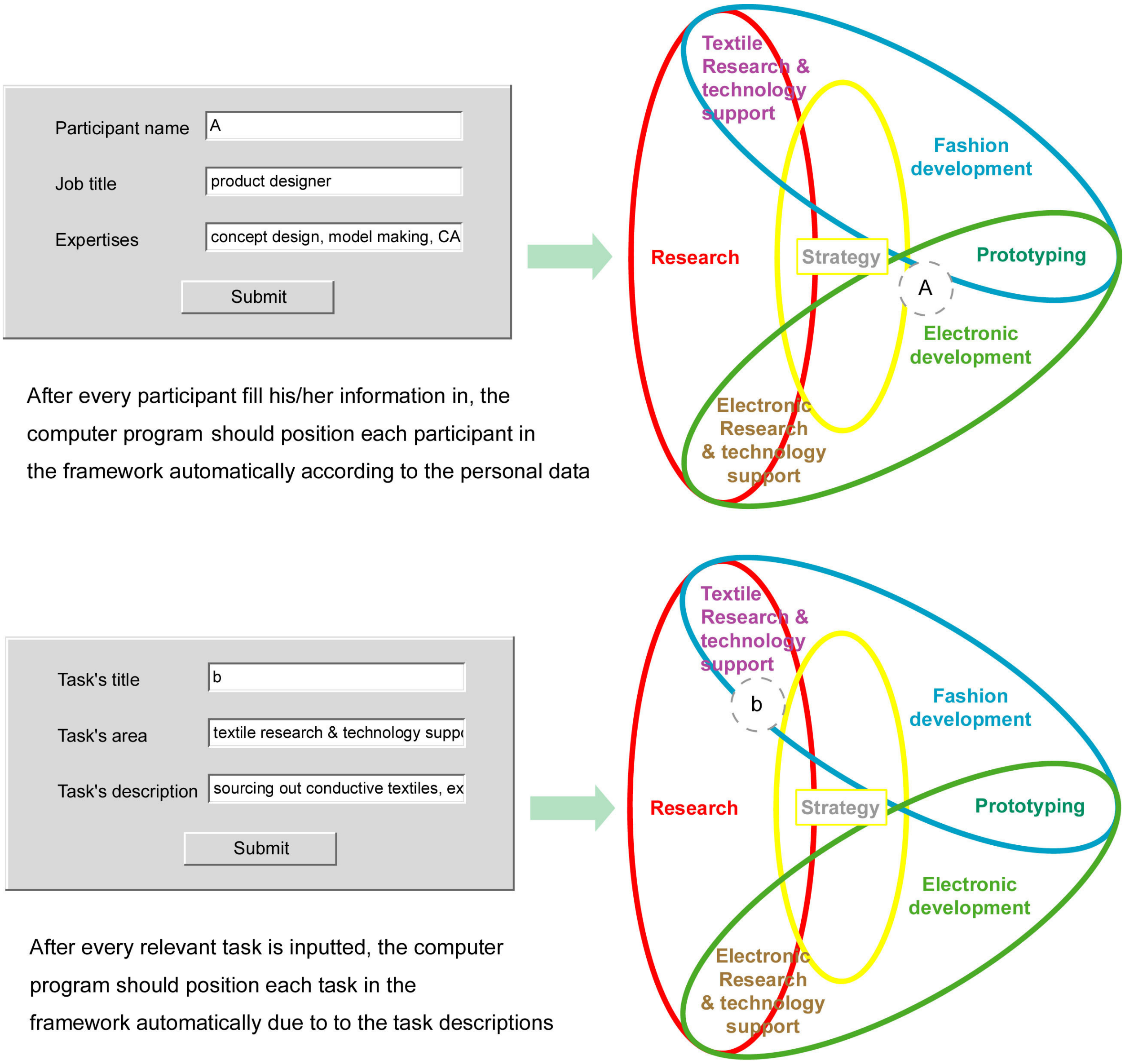

Figure 5.15: The electronic model positions all participants and tasks automatically

The framework that describes the tasks and the one that exhibits the participants' positions must be linked. Consequently, when a particular task is selected, the dialogue box showing who is responsible for this task should be provided (see figure 5.16). In the same way, when a specific name is selected, the dialogue box showing the responsibilities of this participant, the name of the persons he/she collaborates with should be presented.

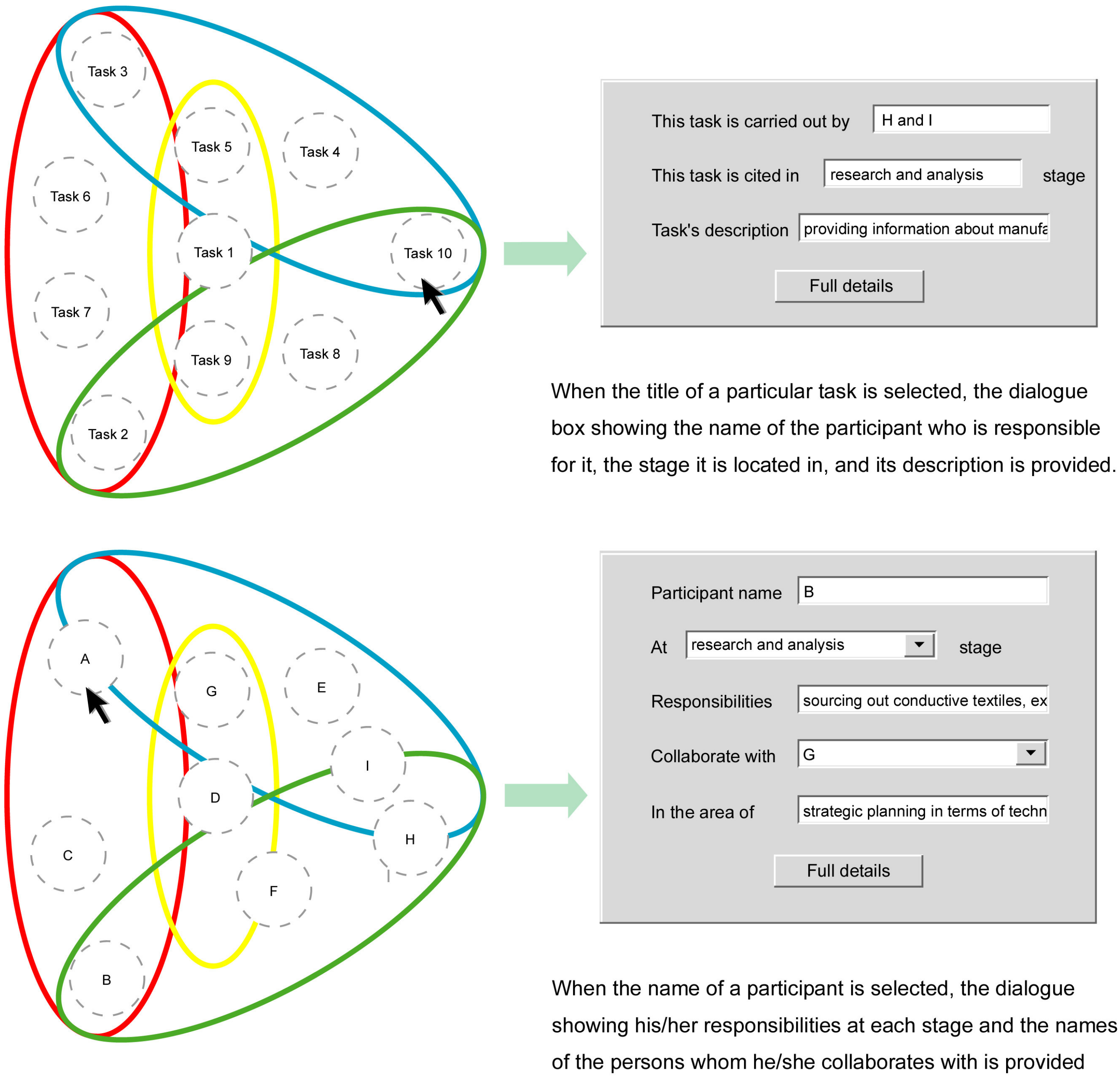

Figure 5.16: Electronic model provides information about tasks and the participants

Furthermore, when the participant decides to extend his/her creative boundary into different areas, the dialogue box showing the name of the person who is responsible for that particular area and the description of the tasks within that area should be shown (see figure 5.17). However, this research is focusing on the conceptual model not the computer program, therefore, the actual electronic version will not be included. Without the automatic computer program, the developers need to position all the participants' names and all the development tasks in the framework themselves. Moreover, in order to see the relationships between the tasks and the participants in the different stages, several frameworks must be compared manually. Nonetheless, the results and the underlying concept of both electronic method and manual method are identical.

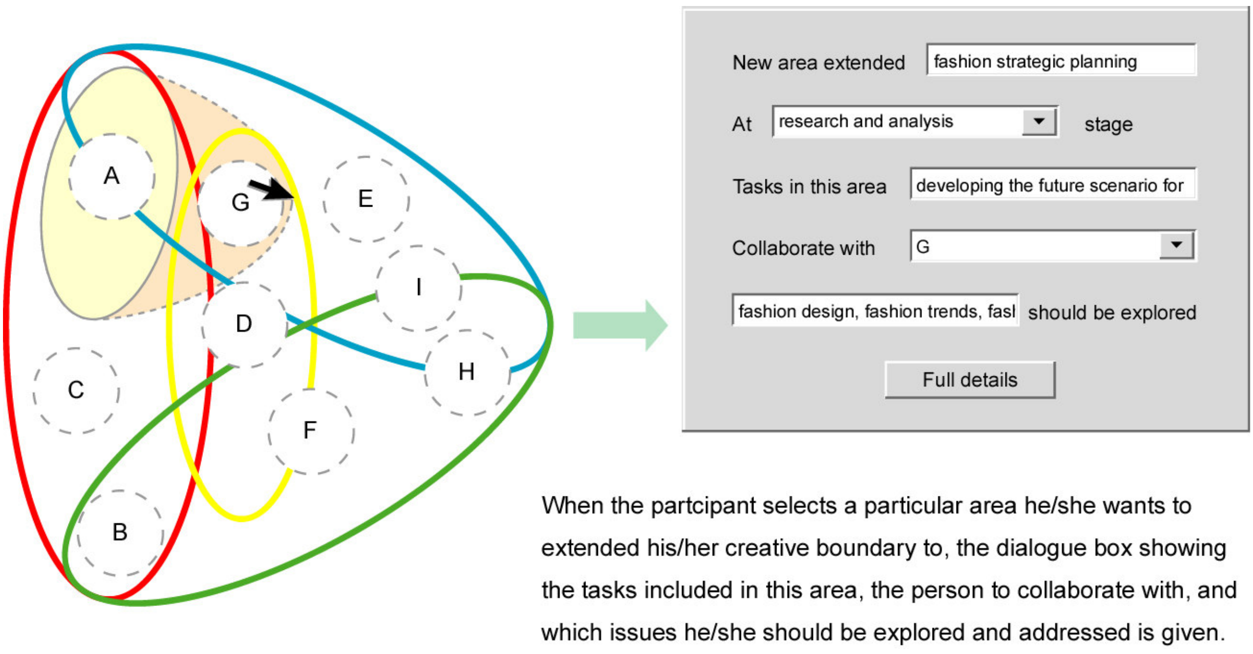

Figure 5.17: Electronic model explains how to extend a boundary into different areas

At the second level, the conceptual model provides the details of all the tasks (see figure 5.13). The detailed framework is suitable when the developers start working, since it describes which tasks should be carried out at which stages. Consequently, this model can be used as a guideline and a checklist throughout the development process. The details illustrated in the framework can be removed, added or combined according to the specific requirements of each development team. Ideally, this detailed model should be constructed in the electronic form as well. In this way, the effort to alter the conceptual model can be minimised. However, without the electronic model, the developers have to alter and compare the information in the different frameworks manually.

At this stage, the procedure of conceptual model formulation in complete. Nevertheless, this conceptual model is not yet the final model. The new conceptual model needs to be validated by its potential users, which are the Smart Clothing developers in the industry. The developers' responses and feedbacks must be addressed in this model in order to make sure that this new model is useful for them. The validation process and the procedure of conceptual model modification will be presented in the next chapter.