The moment of serendipity in technology companies: study by participant observation

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Abstract: The paper aims to present key factors for management to promote generation of serendipity in technology companies, from the practical point of view of repeatable and more predictable ways of thinking for preparation of innovation. First, we analysed six cases of 'the moment' of serendipity that had been collected over two years of participatory observation in a Japanese technology company. Evaluating each case from the point of view of collaborative activities, it is revealed that key collaborative activities are different according to the type of serendipity (pseudo or true). For pseudo-serendipity, 'loose communication' or 'informal exchanges among engineers having similar background knowledge' is important. Meanwhile, for true serendipity, it is desirable to show the element technology that is the result of pseudo-serendipity to a 'gatekeeper' operating in subsystems or system hierarchy, and to promote collaborative activities around him/her at its centre. Key factors for management that encourage and promote sustainable generation of serendipity based on these factual findings are presented, as well as considering a strategy for effective and successful collaborative activities for gatekeepers.

Keywords: R&D management; serendipity; technology-company; gate-keeper; implementation.

Reference to this paper should be made as follows: Itaya, K. and Niwa, K. (2013) 'The moment of serendipity in technology companies: study by participant observation', *Int. J. Environment and Sustainable Development*, Vol. 12, No. 1, pp.72–85.

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This paper is a revised and expanded version of a paper entitled 'Serendipity management model for technology companies' presented at Portland International Conference on Management of Engineering and Technology, Portland, Oregon, USA, August 2011.

1 Introduction

Companies aiming at growing and competing in the forefront of international competition need to create their own new products and businesses. This is especially true for technology companies. Strategies that were once successful at helping a company take the lead, such as improving manufacturing technique and technical approximation, are no longer effective. Companies need to learn how to frequently create innovative new products and businesses using their own potential technology to aid their growth.

How then, should the technology companies address this issue? First, there is the use of marketing methods. Researchers have sought for the most desirable way of marketing for technology companies. von Hippel (1988), for example, studied an example of developing new products in cooperation with lead-users who went a step ahead of the latest needs to create new products or solutions. However, there is a point where expressing needs is difficult even for lead-users (Thomke and von Hippel, 2002). Furthermore, there was a concern that the idea of 'needs oriented' production, which was the basis of marketing, would not be sufficient in the advanced technology society (Niwa, 2006). The method of marketing based on needs-orientation has its own limitations under such a highly competitive condition.

The second method introduced was technology-leading creation of customers based on the concept of technology marketing (Niwa, 2006), proposed as advanced conventional latent needs approach (Kotler and Keller, 2006). Customers cannot imagine what they want in the advanced technology society. Engineers, however, are in the position where they can create new technologic products that will meet interests and needs of customers in the future. Customer creation means that engineers, viewing the trend of the world and technology together, offer customers new life opportunities based on new technology. One of the examples is the latest personal mobile assistant. Generally speaking, however, engineers are not effective at creating life opportunities, since they tend to remain in the technological professional domain and are rather conservative (Katz, 1997). The problems include determining how to propose the measures for supporting this customer creation by engineers and how to train 'new' engineers who can create life opportunities.

The third method studied was the use of serendipity. Serendipity means leading an accidental encounter to some invention or discovery, sometimes by interpreting data from a different point of view. At the technology company's site where trial and error is conducted every day, there are chances for engineers to have accidental encounters. By leading these accidental encounters to inventions or discoveries, they could find a new objective, a seed for unprecedented epoch-making products and businesses. If generation of serendipity can be promoted effectively, it will be a valuable strategy to help technology companies to become front-runners. Of course, there stands up a controversy for its paradoxical relation between accidental encounter and strategy or methodology. However, it is considered to become significant to think about promotion of serendipity, if focused on the practical point of view of repeatable and more predictable ways of thinking for preparation of innovation. Thus the use of serendipity is considered to become one of the most promising approaches to sustainably create innovative new products and businesses in the technology companies.

2 Previous works

In this section, the precedent studies on serendipity, including discovery research, practical use, and support of serendipity are reviewed. To begin with, it is necessary to understand that there are two types of serendipity (Roberts, 1989). One is called pseudo-serendipity, which is the chance to discover what was being sought. The other is called true serendipity, which refers to a discovery made by chance of something that was never considered before.

Examples of pseudo-serendipity are the discoveries of new materials and new drug candidates. By reviewing case studies dealing with the discovery of new materials and new drug candidates (Fujii, 2001; Ishii, 2005; Shook, 2008), we can identify the important factors in the processes to the serendipity. It is important when setting assumptions and considerations, "to stick to your hypotheses and ideas" (Fujii, 2001; Ishii, 2005; Shook, 2008), and "to deepen the insights for the accidental and unexpected results" (Fujii, 2001; Ishii, 2005). In addition, when conducting experiments, it is also clear that "trial and error free from the established theory and emphasizing your own hypothesis and experience" (Fujii, 2001; Ishii, 2005) is important in researchers' behaviour. It can be said that hypotheses of researchers' or engineers' own, as well as trial and error behaviour, are important for pseudo-serendipity.

True serendipity, on the other hand, can be said to include a conceptual change, which leads to an unexpected result. This conceptual-change-approach, which does not assume any specific goal, is considered to be effective in creating targets for unprecedented products and businesses, which was a key concern throughout this study. Regarding conceptual change, Dunbar (1997) showed by participatory observation online, that communication among researchers played an important role in generating hypotheses and collaborative activities. Ueda and Niwa (1996), through case studies on past outstanding inventions and discoveries, have shown the effect of collaborative activities on conceptual change. Thus, collaborative activities can be said to be one of the important factors in generation of true serendipity.

Serendipity, thus, has been studied, mainly regarding its process of occurrence and relevant factors for it. Studies from the point of supporting its interdisciplinary significance, practical use, or reconsideration of its worth of serendipity have been started

recently. Cunha et al. (2010) tried extracting important factors as for supporting serendipity from the aspect of organisational learning. Andre et al. (2009) examined the ways of supporting serendipity from the aspect of computer science, in browsing and web search. Foster and Ford (2003) also studied serendipity in the context of information retrieval and seeking. Graebner (2004) studied mission of leaders as a case study, while generating serendipity in acquisition of the technology companies. McCay-Peet and Toms (2010) tried extracting conditions that 'facilitated' serendipity and pointed out the importance of the 'trigger' that was the starting point of serendipity. Fine and Deegan (1996) discussed and reconsidered the role of serendipity by reviewing lots of relevant papers and articles.

Thus, studies for serendipity, which are distinguished from discussion of traditional creativity or overall innovation, have become one of the significant concerns in lots of fields. However, there has not been done enough research on the measures to encourage serendipity in technology companies from the practical point of view, especially with a focus on the importance of practical support management and its relation to the technology. Itaya and Niwa (2007, 2009, 2011) proposed discovery-site-leading Management, which promotes discovery-oriented intentions of researchers in exploratory research fields and tried to validate its effect by experiments in technology companies. Although it has been one of the preferred studies on serendipity in technology companies, it deals with only scientific and technological discoveries as the object of its empirical research and the range of its suggestion and discussion is limited to pseudo-serendipity.

In order to elicit management that supports serendipity comprehensively in technology companies, it is important to investigate empirically the relation between serendipity of both types. Additionally, a thorough investigation of different management approaches to the generation of serendipity in technology companies provides a deeper analysis of the factors that impact serendipity, as well as exploratory discussions of methods that encourage serendipity.

In this study, the authors, aiming to demonstrate key factors for management to promote generation of serendipity in technology companies and application of serendipity in technology companies, investigated several cases of serendipity in a Japanese leading technology company through interviews and participatory observation for two years. Our studies focused on the practical point of view of sustainable ways of thinking, that is, repeatable and more predictable ways of thinking for the trigger of innovation. After classifying the two types of serendipity, exploratory analysis based on the grounded theory for each case was done with collaborative activities as a framework, important findings for serendipity were extracted and key factors for management were presented.

3 Methods

In this study, participatory observations were conducted in one of the major Japanese technology companies belonging to the manufacturing sector, with more than three thousand billion yen in capital size (alone), employees numbering over thirty thousand (alone), and with annual sales of three trillion yen or more. The cooperation for participatory observation was obtained from a laboratory in the material field in this company's Central Research Center. In this laboratory, research and discovery of materials are undertaken to break through the limitation of conventional semiconductor devices, or to revolutionise material properties using nanotechnology. From January 2009

through December 2010, one of the authors stayed there for two years as a staff member in charge of work restructuring. He was permitted to participate in the meetings, and to make complementary interviews, as well as observe the process of serendipity centring on collaborative activities among researchers. Before the participatory observation, researchers and leaders were interviewed regarding their current research topic, frequency of meetings, communication partners for collaborative activities, and the quality of their meetings. Their strategy, targets and relevant technological terms were collected through interview and listed on the database of the criteria for judgement of discovery that emerging term for the participant is new or known, it is valuable or not.

In this study, serendipity is defined as the accidental discovery of something that turns out to be valuable (Cunha et al., 2010). During the participatory observations, serendipity was recognised based on this definition. According to the definition by Roberts (1989), pseudo-serendipity and true serendipity were distinguished by measuring the relation between the discovery and the target. We considered like this: it is pseudo-serendipity if the discovery is what has been targeted or sought, while it is true-serendipity if the discovery is something that has never been considered or targeted before.

Table 1 Research theme of teams for participatory observation

Team	*Research theme*	*Member*	*Leader*
A	Research on nano-structured materials for wiring	Researcher 1, Researcher 2	Leader 1
B	Research on amplifier with environment materials	Researcher 3, Researcher 4	Leader 2
C	Study of organic material which connects between heterogeneous chips	Researcher 5, Researcher 6	Leader 3

Table 1 shows the attributes of the teams for the participatory observation. To keep validity of the observation as much as possible, following considerations were taken. Any control replacement or change was not done to the organisation of each team or member during this participatory observation. All the related participants in each case of serendipity were listed as described later. The author equally attended the meetings for each team and recorded the reports and information exchanged there. Average amount of observation time for each team was several hours a week, and approximately one hour interview was done for each researcher. While staying at the laboratory, when he had a chance to get information about what could be inferred to be a case of serendipity as described above, interviews were set with relevant members. Researchers may not remember each stage of concept formation and conceptual change (Dunbar, 1997). Therefore, the interviews were conducted as soon as possible, approximately within a month after the serendipity occurred. The interviews were performed by semi-structured interview method. Furthermore, in order to improve the reliability of the data, we referred to the researchers' notes and memos confirming the consistency of the results.

The results of the survey data were analysed with the approach based on the grounded theory-building (Glaser and Strauss, 1967). From the survey data, filed in text, we extracted the key data regarding the exchanged information, assumptions and proposals (narrative), coded them and analysed them to clarify the relationship between serendipity process and management factors (Yin, 1984). We paid attention and took consideration to careful analysis (Suddaby, 2006; Eisenhardt, 1989) as much as possible. However, it

should be commented that we had priority to clarify key factors as hypothesis over precise building of theories, from the view point of implementation.

4 Results and discussion

4.1 Overview of the cases of serendipity

Table 2 lists the cases of serendipity collected and categorised into true or pseudo type and related data are also shown. Within the observation period, six cases were obtained. According to the definition described in Section 3, three were classified into pseudo-serendipity, and the remaining three were into true. Collaborative activities observed here involved two examples of conversations with colleagues and four cases of information exchanges with the persons belonging to the operation division or group companies. In these four cases, both formal and informal information exchanges were observed.

In the cases of pseudo-serendipity classified to the cases 1 and 2, team members were participating in generation of serendipity. In the case 3, the leader of another laboratory and a member of the operation division development department were involved. On the other hand, in true serendipity cases classified to the cases 4 through 6, the leader in charge of the team was involved in the serendipity in all cases. Furthermore, one characteristic is that there involved were the attendees of senior positions, such as a leader of the operation division or the group company, a fellow, and the manager.

4.2 Case details

The following describes the approach to the occurrence of serendipity in each case by narrative segments and its related description of the narrative sections is also involved. Coding results by authors are also indicated as comments in bracket for the main description and narratives.

4.2.1 Case1 (team A)

Researcher 1, whose target was to realise a unique material with nano-structure for wiring of semiconductor devices, had not succeeded in making even material itself, not to mention targeted nano-structure at that time (continuation of failure). Most of all experiments he tried resulted in failure. He told that the clue to the discovery of an effective process was information exchanges with one of his colleagues, Researcher 2, who was also tackling experiments under different conditions. Researcher 1 said, "We were discussing mutually almost everyday, asking how the result of yesterday was, or saying it was like this under such conditions and so on" (loose communications with colleague). One day, Researcher 2 mentioned his conditions to Researcher 1, saying, "I am able to grow the material for the purpose of 'growing' itself under any conditions". For Researcher 1, who had been aiming at low power conditions as possible, Researcher 2's conditions seemed strangely different (change of perspective). He, adhering to low power conditions, said, "Researcher 2's method and conditions looked like to be 'retreat', not 'advance' but 'retreat' for me." Although there was a conflict, Researcher 1 said, "A change of perspective happened on me then. An idea came to me of raising power for a

moment only at the beginning for carrying out 'seed' attachment. Then, after that, we should grow them beautifully under low power condition". Finally, this change of perspective resulted in the discovery of an effective process for a targeted nano-structure for wiring of semiconductor devices.

Table 2 The examples of the collected serendipity

Case	*Team*	*Result of content of serendipity*	*Type*	*Collaborative activities*	*Related participants*
1	A	Idea of the process to effectively achieve targeted nanostructures	Pseudo	Conversations with colleagues	Researcher 1, Researcher 2
2	B	Idea of a mechanism to explain a peculiar phenomenon	Pseudo	Conversations with colleagues	Researcher 3, Researcher 4
3	B	Change of perspective on how to measure a peculiar phenomenon	Pseudo	Informal information exchange with an in-company operating department	Researcher 3, Researcher 4, Leader 2, Leader 4 (leader in other laboratory) Researcher 7 (member of operating department)
4	B	Idea of an innovative wireless system utilising a unique phenomenon	True	Informal information exchange with an in-company operating department Formal information	Researcher 3, Leader 2, Researcher 8 (member of operating department) Leader 5 (leader of operating department)
5	C	Idea to achieve new card technology with both security and multi-function going together	True	Exchange with an in-company operating department	Leader 3, Fellow 1 (fellow of operating department) Fellow 2 (fellow of operating department)
6	C	Proposal of a breakthrough energy saving consumer electronics device	True	Informal information exchange with a development department of a subsidiary	Leader 3, Leader 6 (senior manager of the development department of subsidiary) Leader 7 (senior manager of the development department of subsidiary)

4.2.2 Case 2 (team B)

Researcher 3, whose target was to realise the amplifier with environmental free material was devoted himself to and deadlocked at the elucidation of the mechanism of an anomalous unstable phenomenon (impasse in situation). Researcher 4, one of his co-workers, was advancing his research to Researcher 3 who suspected the cause of heat paying. Researcher 4 wrestled with attention to behaviour of the electron of a high energy state which was a completely different hypothesis. Researcher 3 said, Researcher 4 suggested me, "the effective action could be same in the stage of a trigger whether by the heat or by a high energy electron state,' and then, the change of the perspective arose (awakening for hypothesis of colleague)". He continued, "Basic assumption itself remained as it was, and if I think that the electron of a high energy state bears the first trigger, while it was primitive, but I found that it proved to be effectively explanation for the anomalous unstable phenomenon of an amplifier (modification of hypothesis)". It has resulted in the discovery of the first stage mechanism of the anomalous unstable phenomenon acting as the obstacle for applying to amplifier with environmental free material (discovery of desirable mechanism).

4.2.3 Case 3 (team B)

For Researchers 3 and 4 had continued research of the amplifier by environmental free material. However, the elucidation of the first stage mechanism for causes of an anomalous unstable phenomenon was progressing. The complete elucidation was still in the mist (protracted slump for missing piece of the puzzle). Guessing two persons' such situation of impasse, Leader 2 set up the meeting. The meeting was a kind of informal one. It aimed to exchange information freely with the researcher of a leader class of other laboratory engaged in research and development of similar technology, and the researcher of a development department of operation division (expansion of information exchange). Researchers 3 and 4 attended and they received a kind suggestion, "It may be subsided when measurement is changed. Do you come to measure?" Although instability was not able to be controlled even after re-measurement based on the advice done, it came to obtain change of a new viewpoint (conviction for own hypothesis). It has resulted in discovery of the synthetic model explaining an unstable phenomenon by narrowing down to the mechanism which may be influenced by measurement environment and advancing search (discovery of desired model).

4.2.4 Case 4 (team B)

The serendipity in this case was occurred at the meeting (set up for another purpose) for exchanging information regarding the amplifier by environmental free material (information exchange among diversified members). Researcher 3 who was present with Leader 2 was performing the presentation about the anomalous unstable phenomenon generated when an amplifier was tried to be fabricated with the environmental free material, which has become clear by then, and the elucidation of the mechanism (presentation of innovative element technology as trigger). It was a time of addressing the mechanism of unstable phenomenon generating which he traced "Whether do heat and the electron of a high energy state serve as a 'trigger', and it is generating either the wave which goes back and forth in the material, or vibration". Researcher 8, one of the members of the operating department, who was an expert of the surrounding subsystem

of the amplifier, said, “It is interesting. When using the wave and vibration, was not an amplifier but another function realizable (cogitation for seed idea)?” Furthermore, Leader 5, a leader of the operating department who was engaged in the system layer, and good at the technology trend or customer needs in this field said, “all the radio functions may be able to be realized rather than substitution of some of element functions by this environmental free material. Of course, discussion for the marginal of performance is required. Whichever it makes, this is likely to become an epoch-making radio system (conversion to leaped cogitation)”. It was the moment that the unexpected idea and assumption generated.

4.2.5 Case 5 (team C)

The place where this case of serendipity occurred was set up as a formal one in which even the director of the research centre and a division vice president attended (chance of formal discussion). Leader 3 was reporting the research topic of an organic material by team C as a planned presentation (presentation of innovative element technology as trigger). Fellow 1, a fellow of the department who took charge of the card business, said, “It is interesting. Regarding the chip put into a card in our business, there are several technological problems to be solved, and this technology is likely to become a key for the solution (notice by a gatekeeper)”. The discussion was carried over at the social gathering at the night of the day. Leader 3 said, “This technology could effectively enable to integrate multiple-devices into one chip module. Can’t it be helpful for your chips?” Fellow 1 replied with a disagreeable attitude, “Gathering chips could make it easy to carry out an alteration to improper use (deep discussion with a gatekeeper)”. Then, Leader 3 proposed, “If our material (… omitted…) is well spread around in a card with our original process, it might look like one chip”. Fellow 1 said with an excitement, “That sounds good. It is likely to become an epoch-making card system in which both security and individual setting functions could be realized at the same time. Why don’t we have a further discussion for details with the expert engineers (cogitation of unexpected idea)?” It was the moment of serendipity was born. There conceived was a proposal of a new technology that realised both security and new functions together, starting with a researchers’ report.

4.2.6 Case 6 (team C)

This case was occurred at the development department of subsidiary where the energy saving home electronics are developed. In order to share the technology road map of related issues, Leader 3 visited the subsidiary, and had a presentation of the technical outline of products by team C. Leader 3 pointed out a possibility of applying an organic material developed by team C for the miniaturisation of the apparatus aiming energy saving (presentation of innovative element technology as trigger). The scene was then shifted to free information exchanges. Leader 6, a senior manager of the development department of the subsidiary, said, “(Your proposal) sounds interesting, but isn’t it possible, Leader 3, … I mean I’d like just to know if it’s possible in the future…” He, then, asked if the unique function his team was aiming for a certain kind of home electronic appliance could be improved by this technology (cogitation of seed idea through misunderstanding). Although his idea was a leap in itself, before Leader 3 answered, Leader 7, senior manager of another development department of the

subsidiary, said, "Interesting. Not only improving its original static function but also changing that static function to moving one, like following a person as he/she moves, means that we could offer a totally new added value, doesn't it (conversion to leaped cogitation)?" Information exchanges for the purpose of sharing a technology road map unexpectedly induced the idea of an epoch-making energy-saving household electric appliance.

4.3 Discussions

The following describes an exploratory analysis for occurrence of serendipity. Further, important factors making management which promotes serendipity were extracted, and the management model based on these findings was presented.

4.3.1 Findings

From the case 1 to case 3, which were categorised as pseudo-serendipity, it was a key to serendipity to have resolved the impasse which was induced through the trial and error based on his hypothesis and model by change of perspective or remediation of the hypothesis. It is possible to say that collaborative activities gave this change of perspective and a 'clue' to the remediation of the hypothesis rather than having played a positive role. In the case of generation of pseudo-serendipity, 'loose communication' is considered to be effective as collaborative activities (Finding 1). Furthermore, in this research, it became clear as a new fact that urging positively "informal exchanges among engineers who has close background knowledge" was also effective in order to resolve an impasse (Finding 2).

On the other hand, in the case of true-serendipity which was observed in the case 4 to the case 6, positive collaborative activities were performed with high frequency. Focusing on the feature of the persons concerned with the collaborative activities, performed as one of the coding, we can see the fact that there involved were the attendees of senior positions, such as a leader who keeps the team, a leader of the development department, a fellow, and the manager, rather than the members directly engaged in the research. In the case of generation of true-serendipity, collaborative activities are more organisational and play the critical role (Finding 3).

Below, analysis and discussion are deepened by making an additional framework of a hierarchy (it being systematic) of a technical field in which the persons concerned are engaged. Introduction of the element technology as a result of the pseudo-serendipity serves as a starting point. The 'feeling of excitement' to the new-born discovery stimulates intellectual excitement of the attendees who engaging in a subsystem or a system hierarchy, and could lead to occurrence of the provisional 'temporary idea' in a subsystem hierarchy. Share of innovative element technology among different system hierarchy possibly induce the critical collaborative activities as a trigger (Finding 4).

This temporary idea serves as a step to the leap to conceptual breakthrough in the system hierarchy, which, further, could cause serendipity. In this process, the intention that such a leap is more important than precise technical judgement is crucial, and in some cases, it could be a key to the breakthrough to misunderstand the effect of the element technology, or to be tolerant to the uncertainty of the realisation of it. In the case of generation of true-serendipity, attitude of permissiveness for misunderstanding or

inaccuracy for target technology is important for critical collaborative activities (Finding 5).

The attendees of a senior position who bear a big role in the collaborative activities in true-serendipity occurrence turn out to contribute as something like a gatekeeper Allen (1986) recited, rather than to demonstrate leadership as a manager representing the mission (Katz, 1997). While they recognise the present technology's limits and problems correctly as a node of communication in their field of technology, they lead the collaborative activities to make the maximum of the emerging innovative element technology. In this process, it is considered that changes of hypothetical constraints of condition are made with high frequency. Furthermore, it is also the feature of this process that they give a loose recognition of regarding that serendipity as important. In the case of generation of true-serendipity, the gatekeeper plays the critical role with frequency (Finding 6).

As overall of findings, it was revealed that not a few cases of serendipity were collected in spite of limited periods and resources for participatory observations this time, which showed that there exist reasonable chances for generation of serendipity in technology companies. It should be noticeable that a monotony management is considered to be a danger of eliminating serendipity in the technology companies. A flexible management approach considering the type or the aspect of each serendipity is indispensable, since suitable key factors are entirely different between pseudo-serendipity and true-serendipity as shown below.

4.3.2 Proposal of key factors for management

The key factors for management based on the findings above, which promote generation of serendipity from the practical point of view of repeatable and more predictable ways of thinking in technology companies, are proposed. In this approach, collaborative activities are mainly set as the object of management. The key factors for management are described as follows with management hierarchy and mission of middle manager in the technology companies being considered. First, as the total framework of management,

Key factor 1 We should pay attention to the fact that the suitable collaborative activities are distinguished between two types of serendipity, pseudo-serendipity and true-serendipity.

When it is in the stage of element technology targeting pseudo-serendipity,

Key factor 2 It is desirable to keep the atmosphere that promotes 'loose communications' with colleagues and promote 'informal exchanges' with other engineers who have close background knowledge.

If the element technology is judged to have reached the stage of pseudo-serendipity,

Key factor 3 It is desirable to share that information in the technology companies positively as a 'seed' of true serendipity.

In this case,

Key factor 4 It is desirable to exchange information through 'gatekeepers' operating in subsystems or system hierarchy.

Even without the proper gatekeeper, though, the following guidelines could make it possible to cover for the functions of a gatekeeper toward true serendipity in collaborative activities with the engineers working on a subsystem and a system hierarchy:

1 to lay more emphasis on a leap of imagination than precise technical judgement

2 to be tolerant to misunderstanding element technology or to the uncertainty of realisation

3 to permit changes of various constraints against generating ideas

4 to respect the serendipity, when once occurs.

Sharing the key factors proposed above among management hierarchy and middle manager is considered to effectively promote the generation of serendipity in the technology companies.

5 Conclusions

The paper aims to present key factors for management to promote generation of serendipity from the practical point of view of repeatable and more predictable ways of thinking for preparation of innovation in technology companies. First, we investigated and analysed the cases of serendipity by two years of participatory observation in a Japanese technology company. Analysis of the six cases collected from the point of view of collaborative activities revealed that the key factors were different according to the types (pseudo or true) of serendipity. For pseudo-serendipity, 'loose communication' and 'informal exchanges among engineers having similar background knowledge' is important. Meanwhile, for true serendipity, it proved to be desirable to show the element technology, which is the results of pseudo-serendipity, to a 'gatekeeper' operating in subsystems or system hierarchy, and to promote collaborative activities centring on the gatekeeper. Key factors for management promoting sustainable generation of serendipity based in these factual findings were presented, and also proposed was the strategy to replace the functions of gatekeeper to collaborative activities with following guidelines:

1 to lay more emphasis on a leap of imagination than precise technical judgement

2 to be tolerant to misunderstanding element technology or to the uncertainty of realisation

3 to permit changes of various constraints against generating ideas

4 to respect the serendipity, when once occurred.

The contribution of this study is that the process of the serendipity occurred in the research site of technology companies which has seldom been clarified before was investigated in an exploratory way by participatory observation, and that key factors for management which support the occurrence of serendipity were proposed from a practical viewpoint. It is desirable that management hierarchy and managers of technology companies support serendipity occurrence effectively on the basis of these key factors for management, which could be a seed to a new product or a new business. In this research, however, it should be remarked that its objective fields for investigation were limited to

the material research and that its viewpoint was chiefly focused on collaborative activities. Other important factors should be extracted for other technology fields and other viewpoints. Moreover, at present, the effect of the key factors for management, has not been proved yet. Further investigation and analysis for the general validity of the management model and systematisation of its important factors are considered to be necessary and remain our next challenge.

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