Learning by teaching technological knowledge: conceptual skill development in Japanese overseas subsidiaries

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Abstract
In recent years, knowledge transfer studies have produced a great deal of knowledge on technology transfer in MNCs. However, these studies have focused exclusively on the effects on the recipients of knowledge and not on the effects on the suppliers of knowledge. To fill this research gap in previous studies, this study takes the concept of “learning by teaching” proposed in pedagogy as a clue and demonstrates for the first time the effects on the suppliers of technological knowledge. This study (1) sets the international horizontal transfer of production technology systems among overseas subsidiaries as the research object, (2) obtains original data from 391 Japanese multinational manufacturing subsidiaries through a mail questionnaire survey, and (3) analyses the data through multiple regression analysis and Structural Equation Modeling (SEM). The results revealed that overseas subsidiaries of MNCs can make their production technology systems explicit (making them easier to teach) through technical guidance and thereby develop the conceptual skills of their engineers and operators. The results of this study open up the possibility of developing theories on (1) updating the knowledge base at the supplier of knowledge and (2) building the relationship between the supplier and the teaching materials in knowledge transfer.

Introduction
Firms build competitive advantage by securing resources that are difficult for competitors to imitate and by utilizing them appropriately (Barney 1991). In particular, multinational companies (MNCs) do this by transferring their resources among their...
operating bases located in diverse countries and regions (Bartlett and Ghoshal 1989; Ghoshal and Bartlett 1988). One of the most important resources in recent years is technology (Porter 1985), which has come to be viewed as technological knowledge (Kogut and Zander 1992, 1993; Zander and Kogut 1995). Research on knowledge transfer in MNCs has become popular as international technology transfers among operating bases such as overseas subsidiaries of multinational firms have attracted much attention as a means of securing competitive advantage (Buckley and Casson 1991; Dunning 1980; Noh and Lee 2019; Wahab et al. 2012), and it is mainly viewed as comprising the following three components: antecedents, processes, and effects (McGuinness et al. 2013; Milagres and Burchartha 2019).

First, knowledge antecedents include the following: the ability to absorb knowledge (Gupta and Govindarajan 2000; Schleimer and Pedersen 2014; Szulanski 1996); the depth of the relationship between the management of the headquarters and the management of the international joint venture (IJV) (Dhanaraj et al. 2004); the capability to transfer knowledge (Martín and Salomon 2003; Park 2011); the individual characteristics involved in the relocation process (Minbaeva 2007); the influence of geographical, cultural, and linguistic distances (Ambos and Ambos 2009; Vlajcic et al. 2019); social capital (Chen and Lovvorn 2011); knowledge stock of foreign subsidiaries (Asmussen et al. 2011); language-sensitive recruitment (Peltokorpi and Vaara 2014); the role of expatriates and Inpatriates (Harzing et al. 2016); alliances with sister subsidiaries (Faems et al. 2020); the level of internal and external relational embeddedness of subsidiaries (Ferraris et al. 2020); and the amount and speed of knowledge transferred (De Luca and Cano-Rubio 2019).

Second, the process of knowledge transfer is understood as that by which one social unit learns from or is influenced by the experiences of another (Argote and Ingram 2000), or as the process by which knowledge or expertise related to some aspect of technology is transferred from one user to another (Lavoie et al. 2017). Relationships among members, tasks, tools, and networks (Argote and Fahrenkop 2016), as well as interactions between suppliers and recipients involved in knowledge transfer (Lavoie et al. 2017), have been proposed as frameworks for understanding the process.

Third, the effects of knowledge transfer include an increase in the following for the recipient: knowledge inflow (Harzing et al. 2016; Minbaeva 2007), knowledge creation (Faems et al. 2020; Ferraris et al. 2020), knowledge supply (Asmussen et al. 2011; Harzing et al. 2016), expansion of capabilities (Park 2011), organizational productivity (Peltokorpi and Vaara 2014), the relationship between cultural intelligence and knowledge transfer process (Vlajcic et al. 2019), and speed of knowledge transfer (Chen and Lovvorn 2011).

Previous studies have shown many findings regarding knowledge transfer in MNCs, but not all questions have been answered. These studies have focused on the recipients of knowledge transfer, which usually aims to improve their performance (Argote and Ingram 2000; Li et al. 2014). However, given that knowledge transfer is an interaction between supplier and recipient (Argote and Fahrenkop 2016; Lavoie et al. 2017), the effects of knowledge transfer should not only accrue to the latter but also to the former. Nonetheless, the effects of knowledge transfer on suppliers have received little attention in previous research and comprise one of the research gaps.
The purpose of our study is to fill this research gap on knowledge transfer in MNCs by focusing on the effect of technological knowledge on suppliers. This study focuses on “learning by teaching” in foreign language education, a teaching method for foreign languages developed by Jean–Pol Martin (Aslan 2015, 2017), and its effect on suppliers of technological knowledge (Duran and Topping 2017). When learning a different language, students can develop various skills by teaching that language to others. If we apply this concept of learning by teaching to knowledge transfer, it should be possible for overseas subsidiaries of multinational companies to acquire various skills by teaching technological knowledge to other subsidiaries. However, no research yet exists on knowledge transfer in MNCs that examines the effects of learning by teaching. Therefore, this study aims to clarify what skills are acquired by foreign subsidiaries, which are the suppliers of technological knowledge, through learning by teaching. The contribution of this research is to advance the literature on technological knowledge transfer in MNCs by incorporating our pedagogical findings.

To achieve the above objectives, this study first covers the core concepts and confirms their relevance to previous studies. Then, propositions and hypotheses linking technological guidance and skills are developed, and the data collected through the conducted questionnaire is quantitatively analyzed to verify them. Finally, the theoretical and practical contributions of this study are clarified based on the results of the analysis.

Literature review

Learning by teaching

Studies of technological knowledge transfer have focused on learning in knowledge recipients (Argote and Fahrenkop 2016; Argote and Ingram 2000; Lavoie et al. 2017; Lombardi 2019). A typical example is research on on-the-job training (OJT) (Nguyen and Aoyama 2015), in which knowledge recipients, relying on the concept of “learning by doing” proposed by Levitt and March (1988), obtain technological knowledge based on direct experience. However, although OJT based on learning by doing asserts the importance of direct experience, it still assumes that learning occurs on the recipient side and, therefore, does not pay any attention to learning on the supplier side. The effectiveness of the direct experience of “learning by teaching” has recently begun to be argued in the field of pedagogy, focusing on the interaction between teachers and students in education (Aslan 2015, 2017; Duran and Topping 2017). Learning by teaching is a concept that captures the fact that knowledge providers learn through direct experience, and it expands our understanding of learning through direct experience. Students can learn by doing, and they can also learn by teaching others. However, no research on technological knowledge transfer has yet applied this concept to argue for the effectiveness of learning in knowledge suppliers. As such, this study is an attempt to apply learning by teaching to expand the scope of direct experience in technological knowledge transfer and to confirm the effects of learning on knowledge suppliers.
It is important to point out here that learning by teaching on the knowledge supplier side is a secondary effect of technological knowledge transfer, not the main effect. This is because the main purpose of technological knowledge transfer is to improve the performance of the recipient (Argote and Ingram 2000; Li et al. 2014). However, such spillover is typical in technological knowledge transfer, and several studies have been developed on them at the country, industry, and firm levels (Cervera-Romero et al. 2020). In country-level spillovers, the typical effect is that the host country receives new knowledge on technology and management indirectly through the local subsidiaries of MNCs (Blomström and Kokko 1998; Glass and Saggi 2002; Nursamsu and Hastiadi 2015; Yi et al. 2015; Yunus et al. 2015; Zhang et al. 2010; Zhao 2021). Prior studies on spillovers at the industry level have been concerned with the effect of firms indirectly obtaining technological knowledge from the R&D activities of competitors in the same industry (Aldieri and Vinci 2017; Audretsch and Belitski 2020; Guisado-González et al. 2016; Hájek and Stejskal 2018; Lamin and Ramos 2016; Ramadani et al. 2017; Ryu et al. 2018; Venturini et al. 2019). As for firm-level spillovers, research has been carried out on the effects of headquarters receiving foreign knowledge from returning managers (Tzeng 2018). However, all spillover studies focus on the secondary effect of learning on the recipient side of knowledge, not on the supplier side. Therefore, our exploration is an attempt to extend the literature on spillover by focusing on the secondary effect of learning in knowledge providers.

International horizontal transfer

Multinational firms usually follow the pattern of overseas expansion by exporting and then developing direct investment (Vernon 1966). Since the initial foreign subsidiary is often competitively inferior to local firms, the headquarters transfer technological knowledge to the subsidiary to compete with the local competitors (Hymer 1976). However, as the initial subsidiary gains business experience, it becomes able to assist headquarters and other overseas subsidiaries (Frost et al. 2002). As a result, the initial subsidiary ends up transferring technological knowledge to its headquarters (Frost and Zhou 2005; Håkansson and Nobel 2000, 2001; Kogut and de Mello 2017; McGuinness et al. 2013; Silveira et al. 2017; Subramaniam and Venkatraman 2001; Yang et al. 2008) or fellow subsidiaries in other countries and regions (Gupta and Govindarajan 2000; Hansen 1999, 2002; Schulz 2001; Tsai 2001).

The transfer of technological knowledge from an overseas subsidiary to its headquarters is usually called “reverse” transfer (Frost and Zhou 2005; Håkansson and Nobel 2000, 2001; Kogut and de Mello 2017; McGuinness et al. 2013; Silveira et al. 2017; Yang et al. 2008), and the transfer of technological knowledge from an overseas subsidiary to a fellow subsidiary in another country is called “international horizontal” transfer or “horizontal” transfer (Hansen 1999, 2002; Schulz 2001). This study aims to confirm the effects of learning by teaching on various such transfers of technological knowledge in MNCs, whereby students acquire various skills by teaching others (Aslan 2015, 2017; Duran and Topping 2017). These effects are expected to appear only in international horizontal transfers, where foreign
subsidiaries teach technological knowledge to fellow subsidiaries in other countries and regions. Therefore, this research will focus specifically on international horizontal transfers of technological knowledge in multinational firms.

**Technological guidance**

Prior research on knowledge transfer in MNCs showed that knowledge transfers among subsidiaries consist of two aspects: knowledge supplying activities and knowledge absorbing activities (Gupta and Govindarajan 2000). It has been shown that transferability is important in knowledge supply activities (Martin and Salomon 2003; Park 2011), and absorption is important in knowledge acceptance activities (Cohen and Levinthal 1990; Gupta and Govindarajan 2000; Schleimer and Pedersen 2014; Szulanski 1996). In recent years, an increasing number of studies have captured technology transfer in the concept of knowledge transfer (Ismail et al. 2018; Sadoi 2011; Štrach and Everett 2006). Since knowledge resides in people’s minds, the movement of people, whether in formal or informal forms, is the main form of knowledge transfer (Song et al. 2003). According to these findings of previous studies, technological knowledge transfer may be viewed from two aspects: “technological guidance” and “technological absorption”. Technological guidance is the act of the holder providing technological knowledge to the non-holder, and technological absorption is the act of the non-holder absorbing technological knowledge from the holder.

Furthermore, a subsidiary’s knowledge transfer may involve a party concerned visiting the knowledge supplier’s or recipient’s location, or a party welcomed from the supplier or recipient, and this relationship is shown in Table 1. First, “technological guidance” includes (1) when the supplier of technological knowledge goes to teach at the recipient’s site (Harzing et al. 2016; Shao and Ariss 2020) and (2) when the supplier of technological knowledge teaches the recipient at its site (Nguyen and Aoyama 2015; Suh 2015). Next, “technological absorption” comprises (3) the case where the recipient of technological knowledge is taught when visiting the supplier’s location (Shao and Ariss 2020) and (4) the case where the recipient of technological knowledge is taught when receiving the supplier at its location (Elahi et al. 2018; Subramaniam and Venkatraman 2001).

The purpose of this study is to demonstrate the effects of learning by teaching on the process of overseas subsidiaries teaching technological knowledge to other foreign subsidiaries. Consequently, the research objects of this study are the two types of technological guidance shown in Table 1, namely, technological

| Table 1  | Types of technological knowledge transfer in subsidiaries |
|----------|----------------------------------------------------------|
| Technological knowledge transfer | Types of transfer |
|                  | Visiting                      | Receiving                  |
| Technological guidance | (1) Technological guidance (V) | (2) Technological guidance (R) |
| Technological absorption | (3) Technological absorption (V) | (4) Technological absorption (R) |
guidance (V) and technological guidance (R). As previous studies have not yet clarified the differences in the effects of learning by teaching in these two types of technological guidance, this study tentatively assumes that they are equivalent. Furthermore, it examines the effects in both situations, and in doing so, we hope to expand the literature on technological knowledge transfer.

**Hypotheses and the analytical model**

**Explicitness of the production technology system**

Knowledge is a fluid mixture of acquired experience, various values, skilled insight, and information about a situation (Nonaka and Takeuchi 1995). Prior research on knowledge transfer has covered a variety of prescriptive knowledge, such as marketing, distribution, and purchasing know-how; packaging design technology; product and process design; and management systems (Gupta and Govindarajan 2000). In particular, knowledge about production technology is essential for manufacturing firms to gain a competitive advantage, and its effective creation and utilization is the key to the rise and fall of the companies concerned (Kogut and Zander 1992, 1993; Zander and Kogut 1995).

The following two types of knowledge exist: explicit knowledge, which is characterized by an objective, rational, explicit, metaphysical, and past knowledge; and tacit knowledge, which is characterized by subjective, empirical, physical, and present knowledge (Nonaka and Takeuchi 1995). Many previous studies on knowledge transfer have also used these knowledge concepts to produce useful research results (Argote and Fahrenkop 2016; Milagres and Burcharth 2019). In general, explicit knowledge is easily transferable, but it is also easily imitated and less likely to be a source of competitive advantage. In contrast, tacit knowledge is difficult to transfer and imitate, but it can be a source of competitive advantage. The focus of knowledge transfer research has been to resolve the contradiction of how to effectively transfer difficult-to-transfer tacit knowledge (Subramaniam and Venkatraman 2001).

Based on the above research trends, this study focuses on production technology, in particular technological knowledge, and uses the concept of system, which is the combination or totality of various production technology elements, as a perspective for understanding production technology (Kambayashi 2003). In other words, this study considers technological knowledge as a production technology system that is composed of explicit and tacit knowledge. When technological knowledge is understood as a production technology system, the following relationship is expected to be established between the production technology system and international horizontal transfer: the more explicit (i.e., less tacit) the production technology system is on the supply side, the better the engineers and operators understand the production technology system and the easier it is for them to instruct the receiving side, thus increasing technological guidance (Kogut and Zander 1992, 1993; Zander and Kogut 1995). Therefore, the subsequent proposition and hypotheses can be obtained:
Proposition 1  *The explicitness (non-implicitness) of the production technology system on the supply side increases international horizontal transfers of the production technology system.*

Hypothesis 1a  The explicitness (non-implicitness) of the production technology system on the supply side increases technological guidance (visiting type) in international horizontal transfers.

Hypothesis 1b  The explicitness (non-implicitness) of the production technology system at the supply side increases technological guidance (receiving type) in international horizontal transfers.

### Autonomy of overseas subsidiaries

Foreign subsidiaries exist within the production networks of multinational corporations; they are not fully autonomous entities and can only operate within the range of the autonomy granted by the headquarters of the MNC (Bartlett and Ghoshal 1989; Ghoshal and Bartlett 1988).

Under this autonomy, however, overseas subsidiaries are able to achieve results through a variety of ingenious measures (Gammelgaard et al. 2012; Oki 2016, 2020). Knowledge transfer by these subsidiaries is a part of this process, which is greatly influenced by the autonomy granted by the headquarters (Ghoshal and Bartlett 1988). In this context, the greater the autonomy of the foreign subsidiary, the more room their engineers and operators have for ingenuity and the more active they are in production and development. Since the international horizontal transfer of production technology systems is a part of such activities, those undertaken by overseas subsidiaries can also be expected to increase as their autonomy grows. Consequently, the following proposition and hypotheses can be derived:

Proposition 2  *Foreign subsidiaries’ autonomy increases the international horizontal transfers of production technology systems.*

Hypothesis 2a  Foreign subsidiaries’ autonomy increases technological guidance (visiting type) in international horizontal transfers.

Hypothesis 2b  Foreign subsidiaries’ autonomy increases technological guidance (receiving type) in international horizontal transfers.

### Skill development of engineers and operators

The main purpose of transferring technological knowledge is to increase the recipient’s technological performance (Argote and Ingram 2000; Li et al. 2014), for which skill development is essential (Barros et al. 2020). However, this study proposes that suppliers of technological knowledge can also develop a variety of skills through learning by teaching. In terms of human resource skills in firms, Katz’s skill
typology (1974) has greatly influenced subsequent research (Peterson and Van Fleet 2004; Sunindijo 2015); Katz pointed out three basic skills of managers, which are (1) technical skills, (2) human skills, and (3) conceptual skills.

Technical skills comprise in particular the understanding, mastery, and special activities of methods, processes, procedures, and techniques. They also include particular knowledge, analytical proficiency in specialized fields, and the ability to make substantial use of tools and techniques in such fields (Katz 1974). These can be effectively developed under the supervision and support of supervisors. Human skills refer to the ability of a manager to work effectively as a member of a group and to create a cooperative atmosphere within the team (Katz 1974). These can be developed effectively through self-help and systematic activities under expert leadership. Conceptual skills are related to the ability to see the enterprise holistically, specifically to recognize how the functional divisions depend on each other, how changes in one division affect all other functional divisions, and how individual business units relate to the political, social, and economic aspects of the industry, community, and nation (Katz 1974). Since conceptual skills are concerned with ideas and concepts (Peterson and Van Fleet 2004; Yukl 2002), they can be considered in the context of production as the ability to recognize how individual production technology elements relate to the overall production technology system. These skills can be most effectively developed through coaching; when a supervisor assigns a specific role to a subordinate and the subordinate asks the supervisor for assistance in fulfilling the role, the supervisor does not provide a solution, but rather asks questions and offers opinions to guide the subordinate in finding a solution on his or her own.

Following Katz’s argument above, the development of technical skills has a high affinity with the act of being taught, while the development of human and conceptual skills is closely associated with the act of teaching. In other words, technical skills are more likely to advance through technological absorption, while human and conceptual skills are more likely to be cultivated through technological guidance. Although Katz’s skill typology (1974) was designed for managerial skills, it has the potential to be applied also to other job levels (Peterson and Van Fleet 2004; Sunindijo 2015). The succeeding proposition and hypotheses are presented from this perspective:

**Proposition 3** Technological guidance in international horizontal transfers of production technology systems enhances the skills of engineers and operators in overseas subsidiaries.

**Hypothesis 3a** Engineers and operators in overseas subsidiaries who experience technological guidance (visiting type) enhance their human skills.

**Hypothesis 3b** Engineers and operators in overseas subsidiaries who experience technological guidance (receiving type) enhance their human skills.

**Hypothesis 3c** Engineers and operators in overseas subsidiaries who experience technological guidance (visiting type) enhance their conceptual skills.
**Hypothesis 3d** Engineers and operators in overseas subsidiaries who experience technological guidance (receiving type) enhance their conceptual skills.

**Analytical model**

The basic structure of the above propositions, that is, the analytical model, is shown in Fig. 1. It relies on the results of previous studies, which demonstrated that technological knowledge transfer has the following causal mechanism: factor → process → effect (McGuinness et al. 2013; Milagres and Burcharth 2019). This assumes that the explicitness (non-implicitness) of the production technology system, which is technological knowledge, as well as the autonomy of the overseas subsidiary, both promote the international horizontal transfer of the production technology system, and that the engineers and operators of the foreign subsidiary develop human and conceptual skills through learning by teaching. However, the fact that the overseas subsidiary develops new skills through teaching technological knowledge to a fellow subsidiary in another country does not mean that it is inferior to that subsidiary. Our study assumes a situation in which the teaching subsidiary improves the quality and quantity of its technological knowledge compared to that before teaching while maintaining its technological knowledge superiority over the taught subsidiary. It should be noted that this research’s assumption is that of a situation, where the roles of teacher and student do not change, but rather, where the teacher develops his or her abilities while maintaining his or her position.

**Methods**

**Survey design**

To test the above hypotheses, this study surveyed the overseas subsidiaries of Japanese multinational manufacturing companies. The reasons overseas subsidiaries of Japanese MNCs were selected are that Japanese MNCs have been rapidly increasing their overseas production ratio since the beginning of the 2000s and that they are facing the business challenge of improving the production and development capabilities

![Diagram](image)

Note: “+” indicates a positive influence.

**Fig. 1** Analytical model
of their subsidiaries abroad (Oki 2016, 2020). Therefore, Japanese multinational manufacturing firms are considered to be the best research targets for examining the effects of international horizontal transfers of production technology systems.

Following the method of previous studies (Oki 2016, 2020), we utilized the “Overseas Japanese Companies Data, Text Edition 2019” published by Toyo Keizai Inc. to extract the overseas manufacturing subsidiaries (overseas factories) of Japanese multinational manufacturing companies to be studied. First, we selected foreign subsidiaries that included the terms “production,” “manufacturing,” “assembly,” or “processing” in their business descriptions. Second, we selected overseas manufacturing subsidiaries whose representatives were listed in name and mailed them our questionnaires, to increase the collection rate of the questionnaires as much as possible. Third, we considered the operating period of overseas manufacturing subsidiaries as a proxy variable for the operating period of overseas factories, and we decided to select those that had been operating for at least 5 years at the time the questionnaires were mailed. We chose 5 years as the observation period, because we deemed that it is an appropriate timespan in which the respondents would be able to trace their memories and answer our questions as accurately as possible while avoiding extreme short-term fluctuations. Fourth, we selected 5419 foreign subsidiaries in the top seven countries and regions, where Japanese MNCs have established many overseas subsidiaries, namely, China, the United States, Thailand, Indonesia, Vietnam, Malaysia, and Taiwan. However, due to research budget constraints, we were only able to conduct the questionnaire with a maximum of 3000 companies, so we decided to increase the number of locations surveyed as much as possible and excluded the first-ranked 2394 manufacturing subsidiaries in China from the sample. Accordingly, the survey covered 3025 (39.6% of the total database) overseas subsidiaries of Japanese multinational manufacturing companies located in six countries and regions: the United States, Thailand, Indonesia, Vietnam, Malaysia, and Taiwan. Table 2 shows the selection process for the survey.

Sample

The purpose of the questionnaire and the method of response were explained in detail in the cover letter, and those who were in a position to respond on behalf of the main plant of the overseas manufacturing subsidiary (e.g., plant manager, manufacturing manager, manufacturing section chief, etc.) were requested to provide us their feedback. We obscured the theoretical issues as much as possible so that the respondents would not be influenced by the hypotheses that we intended to test in this study (Chen et al. 2005).

In developing the queries for the questionnaire, this study drew on measures from previous studies that have had a significant impact, especially in the areas of international management, multinational enterprises, technology transfer, and knowledge transfer (Chen et al. 2005; Ghoshal and Bartlett 1988; Zander and Kogut 1995), and using these scales, the questions related to the hypotheses were developed in Japanese. Next, five Japanese researchers, one practitioner in the field of production technology, and seven graduate students were asked to comment on the appropriateness
of the questions, and the wording of the questions was improved. The Japanese questionnaire was then translated into English by a translation company, followed by a back-translation procedure to ensure that the Japanese and English questionnaire items conformed to each other. Furthermore, the questionnaire was also made available online so that respondents would have the option to reply via a dedicated website, to improve convenience and increase their response rate. They were asked to choose either the paper version or the web version of the questionnaire and also to select the language, either Japanese or English, whichever was more favorable for them.

The cover letter (in Japanese and English), questionnaires in printed form (in Japanese and English), and return envelopes (postage paid by the researcher) were posted from Japan to the 3025 (2911 valid mailings) overseas manufacturing subsidiaries on July 25, 2019. We received 391 valid responses (13.4% valid response rate) by mid-November 2019. As most of the previous studies of a similar type in recent

| Countries            | Entire database | Extracted subsidiaries | Cumulative total A | Cumulative total B |
|----------------------|-----------------|------------------------|--------------------|--------------------|
| 1. China             | 6879            | 2394                   | 2394               | –                  |
| 2. United States of America | 4044       | 858                    | 3252               | 858                |
| 3. Thailand          | 2578            | 851                    | 4103               | 1709               |
| 4. Indonesia         | 1338            | 429                    | 4532               | 2138               |
| 5. Vietnam           | 1161            | 340                    | 4872               | 2478               |
| 6. Malaysia          | 1016            | 280                    | 5152               | 2758               |
| 7. Taiwan            | 1136            | 267                    | 5419               | 3025               |
| 8. India             | 891             | 255                    | 5674               | 3280               |
| 9. Korea             | 976             | 251                    | 5925               | 3531               |
| 10. Philippines       | 623             | 167                    | 6092               | 3698               |
| 11. Mexico           | 590             | 153                    | 6245               | 3851               |
| 12. United Kingdom   | 975             | 135                    | 6380               | 3986               |
| 13. Germany          | 865             | 134                    | 6514               | 4120               |
| 14. Hong Kong        | 1311            | 127                    | 6641               | 4247               |
| 15. Brazil           | 459             | 124                    | 6765               | 4371               |
| 16. Singapore        | 1477            | 123                    | 6888               | 4494               |
| 17. France           | 438             | 89                     | 6977               | 4583               |
| 18. Australia        | 611             | 67                     | 7044               | 4650               |
| 19. Canada           | 358             | 57                     | 7101               | 4707               |
| 20. Czech Republic   | 125             | 49                     | 7150               | 4756               |
| Total amount         | 31698           | 7630                   |                    |                    |

“Extracted subsidiaries” is the number of subsidiaries “with manufacturing function”, “with the name of representative”, “in operation for more than 5 years”. Cumulative total A is the cumulative total of the number of extracted subsidiaries, and cumulative total B is the cumulative total excluding China from cumulative total A.
years had valid response rates of less than 20% (Sarkar et al. 2009; Schleimer and Pedersen 2014), we concluded that the rate achieved for our study is not extremely low and can be considered acceptable for analysis. There were no statistically significant differences between the non-respondents and the valid respondents in terms of the number of employees, sales (in US dollars), the number of employees dispatched from Japan, the number of Japanese investment firms, the Japanese investment ratio, and the investment ratio of the largest Japanese firm, except for the years of entry into the overseas location. However, the difference in entry year was less than 2 years, and this was not so substantial as to have a meaningful impact on the operations of the overseas manufacturing subsidiaries. Tables 3, 4, and 5 show the attributes of the sample firms, their distribution by industry, and their distribution by country of location.

Measurements

To test the causal mechanism of the analytical model, this study measured the events of the independent variable at time $t$ and the events of the dependent variable at time $t+1$, so that these variables would have a causal relationship. The measurement method of these variables is explained below.

Skill development of engineers and operators

This study adopted Katz’s concept of three types of skills (1974) to assess the skill development of engineers and operators: (1) technical skills, (2) human skills, and (3) conceptual skills. One of the previous studies that attempted to operationalize these three types was Chen et al. (2005), and we utilized their scale (2005, p. 807) to create our questionnaire and measure the three skills proposed by Katz (1974). The respondents were asked to rate the extent to which the skills of engineers and operators had changed (improved) from 5 years ago in 2019, using a five-point Likert scale (The number of valid responses was 390, and the valid response rate was 99.7%).

Exploratory factor analysis (EFA) revealed that “development of conceptual skills” constituted one factor, but “development of technical skills” and “development of human skills” could not be identified as separate factors (see Appendix). Hypotheses 3a and 3b of this study explained the relationship between technological guidance and the development of human skills among engineers and operators, but since we could not identify a factor for human skill alone, we discontinued testing Hypotheses 3a and 3b and used only Hypotheses 3c and 3d. Since “development of conceptual skills” constituted a factor as initially expected, we referred to it as the “development of conceptual skills” factor and averaged the scores of the corresponding question items to obtain the factor score. This factor showed a Cronbach’s alpha of over 0.7, guaranteeing a high degree of internal validity among the questionnaire items (Nunnally 1978).
### Table 3 Corporate attributes of non-responding and validly responding firms

| Corporate attributes                                      | Non-respondents | Valid respondents | t value | Significance |
|-----------------------------------------------------------|-----------------|------------------|---------|--------------|
| Number of employees                                       | 482.5           | 563.3            | −1.013  |              |
| Sales (in U.S. dollars)                                   | 103621.8        | 88698.6          | 0.437   |              |
| Number of employees dispatched from Japan                 | 4.4             | 5.3              | −1.473  | *            |
| Year of entry                                             | 1996.0          | 1994.1           | 2.503   |              |
| Number of Japanese invested companies                     | 1.3             | 1.2              | 0.460   |              |
| Japanese investment ratio (%)                             | 62.7            | 66.4             | −1.685  |              |
| The investment ratio of the largest Japanese company (%)  | 60.4            | 63.6             | −1.459  |              |

*p < 0.05, **p < 0.01, ***p < 0.001*
Table 4 Industry distribution of non-responding and validly responding firms

| Industries                      | Non-respondents | Valid respondents | Valid mailings |
|---------------------------------|-----------------|------------------|---------------|
|                                 | Number  | %    | Number  | %    | Number  | %    |
| Glass and stones                | 53      | 2.1  | 5       | 1.3  | 58      | 2.0  |
| Rubber products                 | 74      | 2.9  | 16      | 4.1  | 90      | 3.1  |
| Consulting                      | 1       | 0.0  | 0       | 0.0  | 1       | 0.0  |
| Pulp and paper                  | 35      | 1.4  | 3       | 0.8  | 38      | 1.3  |
| Pharmaceuticals                 | 31      | 1.2  | 3       | 0.8  | 34      | 1.2  |
| Wining and dining               | 1       | 0.0  | 0       | 0.0  | 1       | 0.0  |
| Video and sound                 | 1       | 0.0  | 0       | 0.0  | 1       | 0.0  |
| Chemistry                       | 407     | 16.2 | 59      | 15.1 | 466     | 16.0 |
| Chemical wholesale              | 3       | 0.1  | 2       | 0.5  | 5       | 0.2  |
| Freight transportation          | 3       | 0.1  | 0       | 0.0  | 3       | 0.1  |
| Machinery                       | 267     | 10.6 | 40      | 10.2 | 307     | 10.5 |
| Machinery wholesale             | 20      | 0.8  | 1       | 0.3  | 21      | 0.7  |
| Metal products                  | 167     | 6.6  | 27      | 6.9  | 194     | 6.7  |
| Construction                    | 15      | 0.6  | 2       | 0.5  | 17      | 0.6  |
| Mining                          | 9       | 0.4  | 0       | 0.0  | 9       | 0.3  |
| Information/systems/software    | 9       | 0.4  | 0       | 0.0  | 9       | 0.3  |
| Groceries                       | 120     | 4.8  | 27      | 6.9  | 147     | 5.0  |
| Groceries wholesale             | 7       | 0.3  | 1       | 0.3  | 8       | 0.3  |
| Temporary staffing and business contracting | 9 | 0.4 | 0 | 0.0 | 9 | 0.3 |
| Precision equipment             | 47      | 1.9  | 15      | 3.8  | 62      | 2.1  |
| Petrol and coal                 | 2       | 0.1  | 0       | 0.0  | 2       | 0.1  |
| Textile and clothing            | 81      | 3.2  | 7       | 1.8  | 88      | 3.0  |
| Textile and clothing wholesale  | 1       | 0.0  | 0       | 0.0  | 1       | 0.0  |
| Warehouse and logistics         | 9       | 0.4  | 0       | 0.0  | 9       | 0.3  |
| General wholesale               | 3       | 0.1  | 0       | 0.0  | 3       | 0.1  |
| Other services                  | 3       | 0.1  | 1       | 0.3  | 4       | 0.1  |
| Other wholesale                 | 7       | 0.3  | 1       | 0.3  | 8       | 0.3  |
| Other manufacturing             | 122     | 4.8  | 17      | 4.3  | 139     | 4.8  |
| Steel                           | 91      | 3.6  | 14      | 3.6  | 105     | 3.6  |
| Steel and metal wholesale       | 7       | 0.3  | 1       | 0.3  | 8       | 0.3  |
| Electrical equipment            | 365     | 14.5 | 64      | 16.4 | 429     | 14.7 |
| Electrical equipment wholesale  | 8       | 0.3  | 0       | 0.0  | 8       | 0.3  |
| Electricity and gas             | 1       | 0.0  | 0       | 0.0  | 1       | 0.0  |
| Investment businesses           | 3       | 0.1  | 0       | 0.0  | 3       | 0.1  |
| Presiding company               | 7       | 0.3  | 0       | 0.0  | 7       | 0.2  |
| Agriculture, forestry, and fisheries | 15 | 0.6 | 2 | 0.5 | 17 | 0.6 |
| Non-ferrous metals              | 61      | 2.4  | 6       | 1.5  | 67      | 2.3  |
| Transportation equipment        | 453     | 18.0 | 77      | 19.7 | 530     | 18.2 |
| Transportation equipment wholesale | 2     | 0.1 | 0 | 0.0 | 2 | 0.1 |
| Total amount                    | 2520    | 100.0| 391     | 100.0| 2911    | 100.0|
Technological guidance

We devised the following two types of technological guidance in our study: (1) technological guidance (visiting) and (2) technological guidance (receiving). However, it is not easy to quantitatively measure technological guidance at the level of overseas subsidiaries. Although some previous studies have measured technological knowledge transfers in terms of the number of patents (Agarwal et al. 2009; Singh and Agrawal 2011; Ferri et al. 2019), information on patents is not necessarily readily available to us from the countries and regions in this study. Therefore, we decided to develop our scale to quantitatively measure the scale of technological knowledge transfer, by multiplying the number of engineers and operators of the foreign subsidiaries who were involved in technology transfer in the past 5 years (at the time the questionnaire was posted) by the period during which they were involved in technology transfer. Specifically, the scale of technological knowledge transfer was quantitatively measured by asking respondents to rate the scale of technology transfer on a seven-point scale for each question of technology transfer (see Appendix).

Explicitness of the production technology system

Kogut and Zander (1993) and Zander and Kogut (1995, p. 88) have had the greatest influence on subsequent research on the explicitness (non-implicitness) of production engineering systems, so their scales were used to formulate our questionnaire. Respondents were asked to rate the state of the production technology system in their overseas subsidiaries over the past 5 years on a five-point Likert scale.

When we carried out EFA, the factors did not correspond to the questionnaire items as initially expected, so we decided to create a new construct for the explicitness (non-implicitness) of the production technology system according to the results of the analysis. As a result, we extracted the factors “teachability,” “chemical unimportance,” “mechanical unimportance,” “low technology,” and “system independence”, and the factor scores were calculated by averaging the scores of each questionnaire item for each factor (see Appendix). The questionnaire items were created

| Countries of residence          | Non-respondents | Valid respondents | Valid mailings |
|---------------------------------|-----------------|------------------|---------------|
|                                 | Number | %   | Number | %   | Number | %   |
| United States of America        | 674    | 26.7 | 125    | 32.0 | 799    | 27.4 |
| Thailand                        | 756    | 30.0 | 88     | 22.5 | 844    | 29.0 |
| Indonesia                       | 339    | 13.5 | 69     | 17.6 | 408    | 14.0 |
| Vietnam                         | 305    | 12.1 | 27     | 6.9  | 332    | 11.4 |
| Malaysia                        | 226    | 9.0  | 46     | 11.8 | 272    | 9.3  |
| Taiwan                          | 220    | 8.7  | 36     | 9.2  | 256    | 8.8  |
| Total amount                    | 2520   | 100.0| 391    | 100.0| 2911   | 100.0|
on an inverted scale for the chemical unimportance, mechanical unimportance, and system independence factors. All of the constructs achieved a Cronbach’s alpha of 0.7 or higher except for system independence (Nunnally 1978).

**Technological autonomy of overseas subsidiaries**

Ghoshal and Bartlett (1988, p. 375) have had the greatest influence on subsequent research on the autonomy of overseas subsidiaries. We, therefore, also based questions on their scale and used a 5-point Likert scale to measure the state of autonomy of overseas subsidiaries over the past 5 years (at the time the questionnaire was posted).

The EFA showed that Questions 1–3 and Questions 4–6 constituted one factor each, so the former set of questions was designated as the technological autonomy factor and the latter as the organizational autonomy factor (see Appendix). Both factors showed high levels of Cronbach’s alpha and achieved high degrees of internal validity among the questions (Nunnally 1978). However, as the two factors were highly correlated ($r = 0.465, p < 0.001$), we faced the problem of multicollinearity in the multiple regression analysis, which simultaneously uses both factors as independent variables. To avoid this issue, only technological autonomy was taken into account in this study as the autonomy of overseas subsidiaries, since it is generally technological autonomy rather than organizational autonomy that affects the transfer of production technology systems in MNCs.

**Control variables**

In this study, we set the following variables as control variables to control for the impact of the independent variables on the dependent variables: (1) industry—a dummy variable with transportation equipment as the base (0) and each industry as 1; (2) country dummy—a dummy variable with the U.S. as the base (0) and Thailand, Indonesia, Vietnam, Malaysia, and Taiwan as 1; (3) difference in the natural environment; (4) the number of full-time factory employees; (5) the number of Japanese factory employees; (6) years of operation; (7) establishment of acquisitions—a dummy variable with the new establishment as the base (0) and establishment of acquisitions as 1; (8) ratio of R&D to sales; (9) slack management resources (Ghoshal and Bartlett 1988, p. 375); and (10) normative integration (Ghoshal and Bartlett 1988, pp. 374–375) (see Appendix).

**Results**

**Regression analyses**

Table 6 shows the correlations and descriptive statistics among the above major variables. Since the analytical model of this study (Fig. 1) is a multi-stage causal relationship, this study performed ordered logistic regression analysis and linear
Table 6  Main constructs and correlation matrix

| Constructs                        | 1   | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      | 10     |
|-----------------------------------|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1. Teachability                  |     | 1.000  |        |        |        |        |        |        |        |        |
| 2. Chemical unimportance          | 0.174** |     | 1.000  |        |        |        |        |        |        |        |
| 3. Mechanical unimportance        | 0.075 | 0.235*** | 1.000  |        |        |        |        |        |        |        |
| 4. Low technology                 | 0.245*** | 0.094 | 0.056  | 1.000  |        |        |        |        |        |        |
| 5. System independence            | 0.055 | 0.132** | 0.254*** | 0.109* | 1.000  |        |        |        |        |        |
| 6. Technological autonomy         | 0.050 | -0.141** | -0.087 | -0.097 | -0.073 | 1.000  |        |        |        |        |
| 7. Organizational autonomy        | 0.066 | -0.141** | -0.141** | -0.071 | -0.018 | 0.465*** | 1.000  |        |        |        |
| 8. Technological guidance (Visiting) | 0.168** | -0.171** | -0.186** | -0.114* | -0.044 | 0.159** | 0.070  | 1.000  |        |        |
| 9. Technological guidance (Receiving) | 0.187** | -0.145* | -0.223*** | -0.080 | 0.022  | 0.058  | 0.138* | 0.540*** | 1.000  |        |
| 10. Development of conceptual skills | 0.354*** | -0.170** | -0.110* | -0.072 | -0.004 | 0.141** | 0.127* | 0.141* | 0.174** | 1.000  |
| Mean                             | 2.830 | 2.680  | 2.721  | 3.141  | 2.449  | 3.675  | 3.969  | 0.820  | 1.000  | 3.397  |
| Standard Deviation               | 0.800 | 1.573  | 1.296  | 1.052  | 0.853  | 1.043  | 0.982  | 1.406  | 1.397  | 0.811  |
| N                                | 390  | 389    | 391    | 389    | 391    | 387    | 387    | 313    | 313    | 390    |

*p < 0.05, **p < 0.01, ***p < 0.001
multiple regression analysis for each stage of the causal relationship using IBM SPSS to test the propositions and hypothesis groups.

Propositions 1 and 2

First, we tested Propositions 1 and 2 by creating a regression model with two types of technological knowledge transfer, namely, (1) technological guidance (visiting) and (2) technological guidance (receiving) as dependent variables, and (1) the explicitness (non-implicit) of the production technology system and (2) the technological autonomy of the foreign subsidiary as independent variables. The dependent variables, which form the scale of technological guidance, cannot be added up or averaged, because it is not an interval scale, but rather, an ordinal scale. As ordinary linear regression analysis cannot be conducted, we used the ordered logistic regression analysis (Harrell 2001) to determine the probability of modifications in the international horizontal transfer of production technology systems by foreign subsidiaries when the explicitness (non-implicitness) of production technology systems and the autonomy of foreign subsidiaries change.

Table 7 shows the results of this analysis. It should be noted that the rank correlation coefficients between all independent variables (including control variables) were less than 0.5, and when we conducted linear multiple regression analysis with the same analytical model by IBM SPSS, the variance inflation factor (VIF) of all independent and control variables was less than 2.5 (Johnston et al. 2018). Therefore, we can conclude that the problem of multicollinearity did not arise. According to Table 7, it is clear that the technological guidance of international horizontal transfers is positively affected by the teachability of the production technology system and negatively affected by the chemical non-importance in both the visiting and receiving models (Models 3 and 6). In other words, the analysis shows that overseas subsidiaries with chemical (i.e., highly implicit) production technology systems have a higher probability of providing international technological guidance, and foreign subsidiaries with highly explicit (i.e., less implicit) production technology systems are more likely to provide technological guidance to their fellow subsidiaries in other countries and regions. Here, it is shown that the explicitness of the production technology system has both positive and negative effects on the technological guidance of international horizontal transfers, making a judgment on the validity of Hypotheses 1a and 1b difficult. Therefore, we reserve judgment on the validity of Proposition 1. On the other hand, it was also apparent that the technological autonomy of foreign subsidiaries does not affect the technological guidance of international horizontal transfer, and therefore, Hypotheses 2a and 2b were both rejected and Proposition 2 was not supported.

Propositions 3

Next, we created a linear multiple regression model with the conceptual skill development of engineers and operators in overseas subsidiaries as the dependent variable and the following as the independent variables, to test the proposition regarding the development of conceptual skills: (1) the explicitness (non-implicitness) of the
Table 7 Factors for international horizontal transfers of production technology systems

| Dependent variables | Technological guidance (Visiting) | Technological guidance (Receiving) |
|---------------------|----------------------------------|-----------------------------------|
|                     | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
| Control variables   |         |         |         |         |         |         |
| Country (dummy)     | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     |
| Industry (dummy)    | Yes     | Yes     | Yes     | Yes     | Yes     | Yes     |
| Differences in the natural environment | 0.061 | 0.037 | -0.091 | -0.119 | -0.155 | -0.132 |
| Regular employees   | 0.000   | 0.000   | 0.000   | 0.000   | 0.000   | 0.000   |
| Japanese expatriates| 0.040 * | 0.037   | 0.036   | 0.030   | 0.031   | 0.031   |
| Beginning year of operation | -0.007 | -0.006 | -0.006 | -0.006 | -0.005 | -0.005 |
| Acquisition         | -0.179  | -0.035  | -0.036  | -0.288  | -0.209  | -0.210  |
| Rate of R&D expenditures to sales | 0.243 * | 0.240 * | 0.192   | 0.339 *** | 0.327 ** | 0.336 ** |
| Slack resource      | -0.028  | -0.016  | -0.013  | 0.146   | 0.104   | 0.103   |
| Normative integration| -0.052 | 0.006   | -0.046  | 0.213   | 0.199   | 0.206   |
| Independent variables|         |         |         |         |         |         |
| Teachability        | 0.442 * | 0.447 * | 0.543 ** | 0.547 ** |
| Chemical unimportance| -0.229 * | -0.229 * | -0.226 * | -0.228 * |
| Mechanical unimportance| -0.064 | -0.036 | 0.048 | 0.044   |
| Low technology      | -0.222  | -0.188  | -0.130  | -0.137  |
| System independence | -0.136  | -0.129  | -0.047  | -0.047  |
| Technological autonomy| 0.269 | -0.046 | -0.046 |
| -2 Log-likelihood   | 673.357 * | 650.183 ** | 646.536 *** | 725.110 *** | 704.246 *** | 704.118 *** |
| Cox & Snell          | 0.158   | 0.214   | 0.223   | 0.239   | 0.287   | 0.288   |
| Nagelkerke          | 0.173   | 0.234   | 0.245   | 0.256   | 0.308   | 0.308   |
| McFadden             | 0.071   | 0.099   | 0.104   | 0.101   | 0.125   | 0.125   |
Table 7 (continued)

|                    | Technological guidance (Visiting) | Technological guidance (Receiving) |
|--------------------|----------------------------------|-----------------------------------|
|                    | Model 1  | Model 2  | Model 3  | Model 4  | Model 5  | Model 6  |
| B                  | B        | B        | B        | B        | B        | B        |
| N                  | 298      | 297      | 297      | 298      | 297      | 297      |

Ordered logistic regression analysis by IBM SPSS. *p < 0.05, **p < 0.01, ***p < 0.001

Location country (dummy) is a dummy variable with the United States of America as reference 0 and Thailand, Indonesia, Vietnam, Malaysia, and Taiwan as 1. Industry (dummy) is a dummy variable with transportation equipment as reference 0 and the following industries as 1: glass and stones, rubber products, consulting, pulp and paper, temporary staffing and business contracting, other services, other wholesale, other manufacturing, warehouse and logistics, chemical, chemical wholesale, pharmaceuticals, construction, information/systems/software, investment businesses, video and sound, machinery, machinery wholesale, machinery repair, petrol and coal, precision equipment, presiding company, general wholesale, textile and clothing, textile and clothing wholesale, freight transportation, transportation equipment wholesale, agriculture, forestry and fisheries, metal products, steel, steel and metal wholesale, mining, electricity and gas, electrical equipment, electrical equipment wholesale, non-ferrous metals, groceries, groceries wholesale, and wining and dining. The regression coefficients have been omitted for location country and industry.
production technology system, (2) the technological autonomy of the overseas subsidiary, and (3) the technological guidance (visiting or receiving). We performed a linear multiple regression analysis, because the dependent variable forms an interval scale. As the two types of technological guidance are highly correlated (0.540 in Table 6), we created a linear multiple regression model for each type of technological guidance to avoid the problem of multicollinearity and proceeded with the analysis.

Table 8 shows the results of the analysis. Since the rank correlation coefficients between all independent variables (including control variables) were less than 0.5 and the VIFs of all independent and control variables were less than 2.5, it can be

| Dependent variable | Development of conceptual skills |
|--------------------|---------------------------------|
| Constant | β | β | β | β |
| Control variables | | | | |
| Country (dummy) | Yes | Yes | Yes | Yes |
| Industry (dummy) | Yes | Yes | Yes | Yes |
| Differences in the natural environment | 0.022 | 0.027 | 0.007 | 0.010 |
| Regular employees | 0.074 | 0.066 | 0.023 | 0.019 |
| Japanese expatriates | 0.060 | 0.055 | 0.077 | 0.067 |
| Beginning year of operation | −0.155 * | −0.153 * | −0.145 * | −0.141 * |
| Acquisition | −0.096 | −0.093 | −0.095 | −0.095 |
| Rate of R&D expenditures to sales | 0.083 | 0.069 | 0.025 | 0.014 |
| Slack resource | 0.039 | 0.024 | −0.056 | −0.066 |
| Normative integration | 0.079 | 0.071 | 0.062 | 0.055 |
| Independent variables | | | | |
| Teachability | 0.384 *** | 0.376 *** | 0.376 *** |
| Chemical unimportance | −0.018 | −0.016 | −0.016 |
| Mechanical unimportance | −0.060 | −0.057 | −0.057 |
| Low technology | −0.154 * | −0.150 * | −0.150 * |
| System independence | 0.067 | 0.072 | 0.072 |
| Technological autonomy | 0.077 | 0.076 | 0.076 |
| Technological guidance (V) | 0.090 | 0.011 | 0.011 |
| Technological guidance (A) | 0.139 * | 0.067 | 0.067 |
| Adjusted R² | 0.041 | 0.049 | 0.157 | 0.160 |
| F value | 1.389 | 1.461 | 2.414 *** | 2.444 *** |
| N | 297 | 297 | 296 | 296 |

Linear multiple regression analysis by IBM SPSS
*p < 0.05, **p < 0.01, ***p < 0.001
Same as Table 7 for location country and industry (dummy)
concluded that the problem of multicollinearity does not arise here (Johnston et al. 2018). Table 8 shows that neither the visiting type nor the receiving type of technological guidance in foreign subsidiaries affects the conceptual skill development of engineers and operators, but the teachability of the production technology system is found to positively influence it in the overseas subsidiaries (Models 9 and 10). In other words, the analysis shows that the more teachable and explicit (i.e., less implicit) the subsidiaries’ production technology systems are, the higher the conceptual skills of their engineers and operators will be. The results also suggest that conceptual skills will be higher if the overseas subsidiaries’ production technology systems are less low-level and less explicit (i.e., implicit) (Models 9 and 10). However, when we look at Models 7 and 8, which exclude the explicitness (non-implicitness) of the production engineering system and the technological autonomy of foreign subsidiaries, we also find that only technological guidance (receiving type) has a statistically significant effect on the conceptual skill development of their engineers and operators. This raises the possibility that technological guidance has an indirect effect on the conceptual skill development of engineers and operators through the mediation of the production engineering system’s explicitness, rather than a direct effect. Therefore, although Hypothesis 3c of this study can be rejected, Hypothesis 3d cannot be, and a further, separate analysis must be conducted to ascertain the truth of Proposition 3 regarding the development of conceptual skills.

Covariance structure analyses

As a result of the above analysis, we found that technological guidance in international horizontal transfer does not contribute directly to the skill development of engineers and operators in foreign subsidiaries. However, a closer examination of the results reveals an interesting fact that technological guidance is positively correlated with the development of conceptual skills, and the explicitness of production technology systems (especially teachability) is positively correlated with technological guidance and the development of conceptual skills (Table 6). Moreover, the former correlation disappears when linear multiple regression analysis is conducted, while the latter correlation does not disappear even when linear multiple regression analysis is conducted (Models 3 and 6 in Table 7; Models 9 and 10 in Table 8). In other words, the former is a pseudo-correlation, and technological guidance may be related to the development of conceptual skills via the explicitness (teachability) of the production technology system. However, the linear multiple regression analysis method has its limitations to elucidate such a causal relationship among these variables, and the Structural Equation Modeling (SEM), which allows path analysis among variables, is required to be conducted (Byrne 2016). Therefore, in the following, we constructed a new analytical model, shown in Fig. 2, to conduct SEM to test the validity of the following new causal relationship: technological guidance→explicitness (teachability) of the production technology system→development of conceptual skills.
It should be noted that all independent and dependent variables in this analytical model are observed variables calculated as means of multiple question items. The reliability, convergent validity, and discriminant validity of the model were not be tested. However, reliability analyses and EFAs for the constructs were conducted in the Appendix to confirm that there are no particular problems with their reliability, convergent validity, and discriminant validity.

Table 9 shows the results of the SEM analysis on the old analytical model in Fig. 1. Here, we can see that the fit of the model is low, as the Root Mean Square Error of Approximation (RMSEA) is much higher than 0.1 for both visiting-type and receiving-type of technological guidance in international horizontal transfers. Table 10, Figs. 3, and 4 show the results of the SEM for the new analytical model in Fig. 2. It can be seen that the goodness of fit of the model has improved significantly from Table 9, even though the RMSEA is slightly above 0.1 for both analytical models of technological guidance (Byrne 2016). The results of these analyses demonstrate that the following path is statistically significant for both the visiting and the receiving types of technological guidance: technological guidance → explicitness of the production technology system (teachability) → development of conceptual skills. In addition, the path from technological guidance to the development of conceptual skills is also statistically significant in the case of the receiving type of technological guidance. In other words, when an overseas subsidiary teaches its production technology system to a fellow subsidiary in another country or region, the analysis shows that this experience has the effect of indirectly developing the conceptual skills of its engineers and operators while explicitifying (facilitating the teaching of) its own plant’s production technology system.

**Discussion**

One of the gaps in previous research on knowledge transfer in MNCs is that its effects on suppliers have been overlooked, as the interest of previous studies has been in updating the knowledge base of the recipients of knowledge transfer, not
Table 9 Covariance structure of the old analytical model

| Technological guidance (visiting) | B   | Standard error | $\beta$ | $T$ value | Probability |
|----------------------------------|-----|----------------|---------|-----------|-------------|
| Technological guidance $\leftarrow$ Teachability | 0.340 | 0.097 | 0.192 | 3.516 | *** |
| Technological guidance $\leftarrow$ Technological autonomy | 0.237 | 0.074 | 0.174 | 3.187 | ** |
| Development of conceptual skills $\leftarrow$ Technological guidance | 0.095 | 0.032 | 0.167 | 3.023 | ** |
| Teachability $\leftarrow$ Technological autonomy | 0.340 | 0.097 | 0.192 | 3.516 | *** |

Chi-square = 50.548, d.f. = 2, $p=0.000$, NFI = 0.346, CFI = 0.280, RMSEA = 0.252, AIC = 75.548

| Technological guidance (receiving) | B   | Standard error | $\beta$ | $T$ value | Probability |
|-----------------------------------|-----|----------------|---------|-----------|-------------|
| Technological guidance $\leftarrow$ Teachability | 0.373 | 0.097 | 0.212 | 3.864 | *** |
| Technological guidance $\leftarrow$ Technological autonomy | 0.099 | 0.074 | 0.073 | 1.329 | |
| Development of conceptual skills $\leftarrow$ Technological guidance | 0.114 | 0.032 | 0.197 | 3.598 | *** |
| Teachability $\leftarrow$ Technological autonomy | 0.042 | 0.042 | 0.986 | | |

Chi-square = 50.434, d.f. = 2, $p=0.000$, NFI = 0.338, CFI = 0.268, RMSEA = 0.249, AIC = 74.434

Maximum likelihood method by IBM SPSS Amos. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$
of the suppliers (Argote and Fahrenkop 2016; Argote and Ingram 2000; Lavoie et al. 2017; Lombardi 2019). To fill this gap, we focused on the pedagogical concept of learning by teaching to identify the effects of developing conceptual skills in knowledge transfer suppliers. We thus revealed that knowledge is updated even

Table 10 Covariance structure of the new analytical model

| Technological guidance (visiting) | B   | Standard error | β   | T value | Probability |
|----------------------------------|-----|----------------|-----|---------|-------------|
| Technological guidance           | <-  | Technological autonomy | 0.239 | 0.075   | 0.177       | 3.182 ** |
| Teachability                     | <-  | Technological guidance | 0.105 | 0.031   | 0.185       | 3.358 ***|
| Development of conceptual skills | <-  | Teachability        | 0.341 | 0.049   | 0.337       | 7.022 ***|
| Development of conceptual skills | <-  | Technological guidance | 0.037 | 0.031   | 0.065       | 1.203    |
| Development of conceptual skills | <-  | Technological autonomy | 0.088 | 0.037   | 0.113       | 2.345 *  |

Chi-square = 51.462, d.f. = 8, p = 0.000, NFI = 0.819, CFI = 0.835, RMSEA = 0.118, AIC = 89.465

| Technological guidance (receiving) | B   | Standard error | β   | T value | Probability |
|-----------------------------------|-----|----------------|-----|---------|-------------|
| Technological guidance            | <-  | Technological autonomy | 0.100 | 0.076   | 0.075       | 1.329    |
| Teachability                      | <-  | Technological guidance | 0.113 | 0.031   | 0.197       | 3.588 ***|
| Development of conceptual skills  | <-  | Teachability        | 0.332 | 0.049   | 0.328       | 6.834 ***|
| Development of conceptual skills  | <-  | Technological guidance | 0.061 | 0.031   | 0.106       | 1.984 *  |
| Development of conceptual skills  | <-  | Technological autonomy | 0.091 | 0.037   | 0.117       | 2.474 *  |

Chi-square = 45.623, d.f. = 8, p = 0.000, NFI = 0.838, CFI = 0.856, RMSEA = 0.110, AIC = 83.623

Maximum likelihood method by IBM SPSS Amos. *p < 0.05, **p < 0.01, ***p < 0.001

Note: “e” means an error term. A solid line means statistically significant. A dotted line means statistically not significant. “*+” means a positive effect.

Fig. 3 Verification results in technological guidance (visiting)
among knowledge suppliers, and that this update is not necessarily the same as that of recipients. If the knowledge suppliers in knowledge transfer can update their knowledge base through the experience and become agents of organizational knowledge creation, then the choice of who to entrust with knowledge supply (teaching) in the organization becomes an important focus for both researchers and practitioners (Nonaka and Takeuchi 1995). As this study demonstrated that knowledge suppliers in knowledge transfer can also be important players in organizational knowledge creation, research on what attributes and relationships of knowledge suppliers in knowledge transfer lead to the most effective knowledge updating and creation may become popular in the field of knowledge management theory in the future. This opening up of new research possibilities in knowledge transfer theory will become one of the theoretical contributions of this study.

Few studies have also focused on the role of knowledge-mediating instructional materials in the study of knowledge transfer (Argote and Fahrenkop 2016; Argote and Ingram 2000; Lavoie et al. 2017; Lombardi 2019). Our research has demonstrated that technological guidance leads to the explicitness of teaching materials (production technology systems) and that the suppliers’ conceptual skills are developed through this process. Therefore, it is important to design appropriately the relationship between suppliers and teaching materials for the suppliers’ learning in knowledge transfer. In addition to the perspective of who should supply the knowledge, it appears that we also were able to clarify the viewpoint on what kind of materials should be used for teaching to train suppliers effectively. This is another theoretical contribution of this study.

Conclusions and limitations

This study has been discussed to fill the research gap on knowledge transfer in MNCs by focusing on the effects of international horizontal transfer of technological knowledge on suppliers. The contributions of this study may be twofold. The first contribution is that fills a gap in previous research that has focused mainly on the
effects on the recipients of technological knowledge, and it opens up new possibilities for research that focuses on the effects on the suppliers of technological knowledge. We applied the pedagogical concept of learning by teaching to demonstrate that the process of teaching production technology systems to overseas subsidiaries in other countries and regions promotes the explicitness of their production technology systems while developing the conceptual skills of their engineers and operators. The application of pedagogical knowledge to management research and the acquisition of new knowledge is considered to be academically significant contributions.

The second contribution of this study is that the author’s original data on the overseas subsidiaries of Japanese multinationals were used to derive the study results. This study conducted a mail questionnaire survey of 3025 overseas subsidiaries of Japanese multinationals located in the USA, Thailand, Indonesia, Vietnam, Malaysia, and Taiwan, and received valid responses from 391 companies (valid response rate of 13.4%). In recent years, companies around the world have been tightening their information controls, and the response rate for questionnaire surveys has been declining in response. Even in previous internationally recognized studies in the field of international management, achieving a valid response rate of 20% has become an extremely difficult task. Under such circumstances, the 391 sample size and 13.4% valid response rate obtained by this study are not extremely low, but rather a healthy result. The second contribution of this study is that it is the first to report the results of a study derived using its original data.

The practical implications of this study can be considered as follows. In recent years, the importance of company-wide sharing of technological knowledge has been asserted in the management of MNCs. The rationale for this assertion was that company-wide sharing of technological knowledge from each of their operating bases would bring about economies of scope for MNCs (Bartlett and Ghoshal, 1989; Ghoshal and Bartlett 1988). However, as our study has shown, if MNCs can achieve conceptual skill development of their engineers and operators—not only when they receive technical knowledge from other operating bases, but also when they teach their technological knowledge to other bases—then it would be better for them to actively seek to teach their skills and knowledge to other operating bases to improve their production capacity. Such an outcome could be called an economy of learning, where MNCs develop core production technology systems at their parent factories in their home countries and regions and transfer these abroad, while they can also play a role in actively encouraging their overseas subsidiaries to develop and transfer peripheral production technology systems. This study appears to have been able to provide a rationale for international management based on such economies of learning.

Finally, we would like to mention the limitations of this study and future research topics. First, we referred to Chen et al. (2005, p. 807) in developing the constructs for the skills of engineers and operators in overseas subsidiaries. However, the scale in that exploration was developed for managers of Chinese state-owned enterprises, not for engineers and operators in factories, so it may not have captured the skills of engineers and operators in factories appropriately. In the future, it will be necessary to develop a new construct that more accurately captures the skills of factory engineers and operators. Second, this study obtained both independent and dependent
variables with subjective data. At the same time, the same person was asked to evaluate both variables. In the future, it will be necessary to validate the analytical model of this study by obtaining objective data for the dependent variable in particular, or by obtaining subjective data from a different rather than the rater of the independent variable. Third, to verify the validity of the causal mechanism (technological guidance \(\rightarrow\) explicitness [teachability] of the production technology system \(\rightarrow\) development of conceptual skills) revealed in this study, it is necessary to wait for the implementation of case studies that excel in the verification of causal mechanisms (Yin 1994). Reinforcing the validity of the results of this study by achieving methodological triangulation is also a subject for future research.

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**Data availability** The data sets generated and/or analyzed during the current study are not publicly available, to protect the confidentiality of responding companies.

**Code availability** Not applicable.

**Declarations**

**Conflict of interest** On behalf of all authors, the corresponding author declares that there is no conflict of interest.

**Consent to participate** Questionnaire responses were collected under the respondents’ real names with the promise that individual answers would not be made public.

**Consent for publication** Participants in the questionnaire survey were asked to agree that (1) only the aggregate data obtained would be published, and (2) the results of data analysis would be published in academic journals.

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