考 試 科 目	管理文獻評析	所　別	科技管理研究所	考 試 時 間	5 月 21 日（六）第 1, 2 節

本試題（總計 **10** 頁）涵蓋一篇長篇的論文，在論文之後，有五個問題（在最後一頁），請在仔細閱讀完文章後，就此五個問題，提出你的回答。

Internationalization of research and development: the case of Taiwanese firms

1. Introduction

Owing to the increasing demands of market internationalisation and strategic technological alliances, companies in both industrialized and newly industrialized countries are increasing their international technological innovation and product development efforts. While this issue is important to multinational corporations, most of them continue to have more questions than solutions regarding management practices. Therefore, thorough case studies must be undertaken to clarify the mechanisms for global R&D. Additionally, most previous research is focused on the situations of developed economies, meaning the issue still needs to be studied from the perspective of developing countries.

This study explores the following questions:

1   What are the major motivations driving global R&D?
2   How are international R&D units organized?
3   Do hardware and software companies differ in managing global R&D?
4   What are the mechanisms for coordinating global R&D and international technology transfer?

2   Background

2.1 Trend for Internationalisation of R&D

Chiesa & Manzini [1] pointed out that R&D has been traditionally treated as the last activity to be internationalized. Few companies other than the very largest multinational corporations have much experience of managing global R&D. Nevertheless, R&D activities abroad have recently increased markedly during the past few years [1, 2, 3]. Peters [4] also mentioned that the number of international R&D units of U.S. corporations grew significantly during the 1980s. Similarly, Niosi [5] found that overseas subsidiaries of Canada's multinational companies account for a greater percentage of patents than their home-based corporations. Additionally, these companies intend to build their core competence contributed mainly from the subsidiaries.

Firms in some developing countries, particularly four dragons of Asia, have shown a similar trend [6]. For instance, Taiwan's computer information industry ranks in the top four in the world in terms of output and derives more than eighty percent of its revenues from overseas. Companies in this industry thus naturally consider building R&D units abroad. Furthermore, many of MNCs have recently built their foreign R&D centres in both China and India due to these two countries' recent economic boom [7, 8].

<div align="center">(TO BE CONTINUED ON NEXT PAGE)</div>

考　試　科　目	管理文獻評析	所　　　別	科技管理研究所	考 試 時 間	5 月 21 日(六)第 1, 2　　節

2.2 The Motivations for Internationalisation of R&D

Businesses must decide whether to concentrate R&D resources in central laboratories or to distribute them more widely. Meanwhile, a similar decision must be made regarding internationalisation. Etemad and Dulude [9] pointed out that a company gains an advantage of critical mass by concentrating R&D resources at home country headquarters. However, the higher cost of collecting technical information overseas is the disadvantage of taking this approach. On the other hand, dispersing R&D resources worldwide helps a company to develop more local-market-oriented product, although the downside comes in the form of higher communication cost [10]. Florida [3] investigated 186 technical units of foreign companies set up in the U.S. and found that their major purposes were as follows: 1 create new product concepts; 2 obtain local information; and 3 access high quality scientists, engineers, and designers. Chiesa [11] used centrifugal and centripetal forces as a basis for describing the motives of centralized and decentralized resources during the globalisation of R&D. Meanwhile, Duyester and Hagedoorn [2] indicated that the driving forces of distributing R&D resources worldwide include: 1. enhancing the capability to respond to customer needs; 2. responding to the regulations of local government; 3. making it easier to connect to high quality local suppliers. Other scholars mentioned that distributing R&D resources is an important means of gaining exposure to global technologies [12, 13]. Finally, Sakakibara and Westney [14] pointed out that establishing local R&D units abroad is the best way to learn external technology.

Thus, the major reasons for globalizing R&D can be divided into two categories, namely technology-oriented and market-oriented. While some firms regard access to technical knowledge, information, and human resources as the major benefits of globalizing R&D, others consider access to market and customers more important.

2.3 Organizing for Global R&D

Kuemmerle [15] grouped corporations with technical units overseas into two types: home-based-augmenting and home-based-exploiting. The former describes units that leverage the technologies of local universities, research institutes, or even competitors in the host country. Thus, the major information flow is from overseas back to the home country. Many instances of this kind of arrangement exist. For example, numerous non-U.S. firms assign R&D professionals to join the industrial liaison programs of famous universities, such as MIT, Stanford, and so on. In another example, many multinational telecommunications corporations (such as NEC, Siemens, Matsushita, Alcatel) have built R&D centres close to Bell Labs and Princeton University. The second approach involves establishing R&D units close to market and production plants, aiming to accelerate commercialisation. Numerous examples of this phenomenon can also be found throughout the past decade. Many international companies first establish overseas production facilities, then build a R&D centre nearby because of increasingly complex product technologies, hoping to smooth the transition from the R&D to production. Chiesa [11] used the concept of technological innovation networks to analyse three major types of global R&D activities: technological development; product development; and technical support. In the first type, the company's R&D unit in the home country is the major location of R&D, meaning that, the major purpose of the overseas units is to collect and feedback the relevant technical information. Regarding the second activity, the firms set up R&D units in such a way

備　　　　　註	試　題　隨　卷　繳　交

考 試 科 目	管理文獻評析	所　別	科技管理研究所	考 試 時 間	5 月 21 日（六）第 1, 2　節

as to exploit local strengths. For example, Ericsson has development centres in Australia, Italy and Finland for silicon and chip design, while its centres for developing mobile telephone systems are located in Germany, France, Spain and Greece. The central aim of this approach is to globally integrate technological development. Finally, overseas R&D units focused on technical support are included in either production plants or marketing branches.

2.4 Technological Strategy and Innovation Process for the Globalisation of R&D

New technology, which is essential to company growth and competitiveness, can be developed either internally or externally. While in-house R&D remains vital, the strategic importance of external technology sources has recently increased significantly [16]. Mansfield [17] compared the performance of U.S. and Japanese firms and found that the latter were able to gain a competitive advantage by smartly leveraging external technology sources. Interestingly, Houlder [18] indicates that global spending on external R&D has increased from 12% to 35% as a percentage of total R&D expenses. Meanwhile, the figure for Japanese firms has grown from 40% to 60%.

Many scholars have adopted the concept of transaction costs to analyse companies' choices to control outside uncertainty [19, 20]. If the uncertainty of the transaction is too high, the firm will choose to develop internally. When the transaction is certain, the company will consider using the contract and "market" to manage the situation. However, Powell [19] pointed out that other types of organizations, networks, between market and corporate hierarchies, exist. In fact, networks and strategic alliances can be used to bring obvious advantages to companies [21, 22]: 1 quickly get technology; 2 obtain economies of scale in R&D; 3 broaden the knowledge base; 4 encourage and stimulate internal innovation; and 5 reduce the risk of R&D risks. Regarding the internationalization of R&D, firms can rely internally on their overseas R&D units for technologies needed directly through other "external" ways such as licensing, contract R&D, cooperative research, direct investment, joint ventures, and mergers and acquisitions. The relationship between internal and external R&D is actually complementary, and they are not a substitute for one another.

Other major issues related to global technological R&D strategies may include the strategic thinking of the technology leaderhship versus followership and the level of competence to build.

2.5 Communication

Successful technological innovation and product development involves intensive communications, not only among R&D personnel, but also between R&D personnel and other functions. Numerous studies have found that communication is a crucial influence on performance. Communications is even more critical in the transnational R&D activities. Examining a R&D communication network, Tushman [23] found that engineers and scientists always use "face-to-face" oral communication for information exchange because it makes relevant information real-time and quick feedback possible. Tushman's research also indicated that different types of projects, such as research, development, and technical services, require different communication patterns. Medcof [24] used a systemic approach to explore the communication and organization of global R&D. Medcof categorized the international projects into three types, like Tushman and then (TO BE CONTINUED ON NEXT PAGE)

備　　　註	試 題 隨 卷 繳 交

考 試 科 目	管理文獻評析	所　別	科技管理研究所	考 試 時 間	5 月 21 日（六）第 1, 2　節

analysed how global R&D can be integrated with marketing, manufacturing, or both. Since the various functions might be located in different countries, communication among them becomes complex. Additionally, a phenomenon well known to practitioners is the "not-invented-here (NIH)" syndrome. This phenomenon occurs as technological information introduced into the organizational unit from outside sources fails due to a lack of internal support. One of the reasons for this phenomenon, explained by Martin [25], is that externally conceived technology is "threatening", possibly reflecting badly on the professional competence of internal staff.

2.6 Use of Information-communication technology (ICT)

As the R&D activities become increasingly globalized and dispersed, enhancing communication among distributed R&D units becomes a fresh challenge. Boutellier, Bacho and Roux [26] studied the case of IBM in detail, showing that globally dispersed R&D team can overcome communication and coordination barriers through the use of information technologies and project management software. The tools required to overcome the above problems vary for different stages. For example, face-to-face meetings are important in the early stage, when socializing and building trust are important. Furthermore, database techniques might be critical in collecting information about the customer needs. On the other hand, communication through the intranet, e-mail system, and groupware may be sufficient during the development stage, by which time the informal network has matured. McDonough and Kahn [27] investigated how "hard" technologies (information and communication) and "soft" technologies (managerial behaviors) affect global product development performance. The above investigators found that the frequency of use of hard technologies is greater for higher than for lower performing global teams. Additionally, the set of hard technologies perceived to be important is different for higher versus lower performing global teams.

The above demonstrates, that information technology has always been an auxiliary tool to research activities, and that its role becomes even more important as the communication technologies become more advanced and the R&D activities become more distributed. The basic roles of ICT include: 1 coordinating dispersed projects; 2 exchanging technical information; 3 enhancing the creativity and quality; 4 forming individual networks and building trust. Nevertheless, ICTs remain unable to substitute for face-to-face contacts. Both are actually complementary.
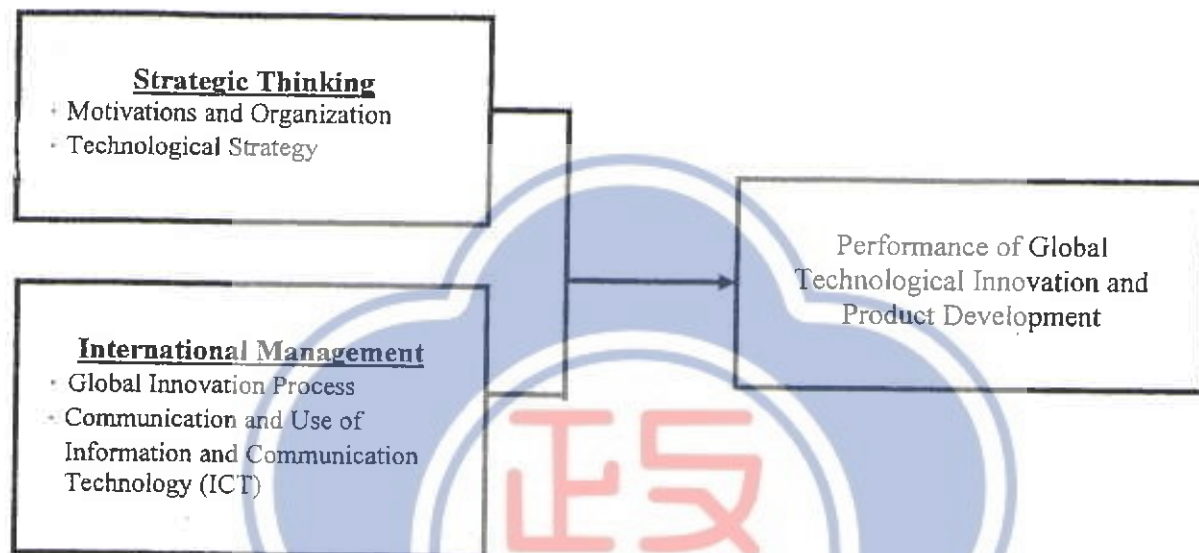
2.7 Research Framework

According to the literature review, the trend which the firms from developing economies internationalise their R&D can be gradually recognized. However, the motivations of different companies conducting R&D overseas may vary. The motivation variable is viewed as an important factor affecting how industrial corporations leverage their international resources to devise and support global R&D strategies. Research has also shown some companies that are more experienced or capable in managing global R&D may implement better international technological strategies. In addition to strategy-level thinking, the firms also need to be concerned with operation-level skills while managing international R&D activities. As many scholars mentioned, communication is a critical issue in the internationalisation of R&D. Firms need to figure out how global innovation process can be managed in order to reduce the

(TO BE CONTINUED ON NEXT PAGE)

備　　　　註	試 題 隨 卷 繳 交

| 考　試　科　目 | 管理文獻評析 | 所　別 | 科技管理研究所 | 考試時間 | 5月21日(六)第1,2　節 |

communication barriers. Furthermore, another key issue to consider is how they can utilize ICTs to enhance their communication effectiveness and global innovation performance. Consequently, the author has developed the research framework (see Figure 1) as the focus of this study.

Figure 1 The research framework for the study of internationalisation of R&D

Strategic Thinking
- Motivations and Organization
- Technological Strategy

International Management
- Global Innovation Process
- Communication and Use of Information and Communication Technology (ICT)

Performance of Global Technological Innovation and Product Development

3　Research Methodology

Regarding the effective management of global R&D, most companies continue to have more questions than answers. Therefore, this study can still be regarded as exploratory, especially from the perspective of developing countries like Taiwan. The use of case study approach for better understanding is thus appropriate [28]. As to the case selection, Yin [29] mentioned that three issues: the unit of analysis, the criteria for selecting cases, and case screening need to be addressed. For the first issue, the study suggests the analysis at the corporate level would be appropriate because the purpose of the research is to explore firms' strategic thinking and international management in global innovation process. As far as the criteria for selecting cases are concerned, the researcher argues that software companies should be included in the samples for the study because the worldwide revenues generated from software sector have been greater than those from hardware sector in the information industry since the end of 1990s. Furthermore, serveral studies indicated that there are differences between managing software development and hardware development [30, 31]. Therefore, it would be worthwhile to expand the studying issue (TO BE CONTINUED ON NEXT PAGE)

| 備　註 | 試　題　隨　卷　繳　交 |

| 考　試　科　目 | 管理文獻評析 | 所　別 | 科技管理研究所 | 考　試　時　間 | 5 月 21 日（六）第 1, 2 節 |

into the area of managing global innovation, with potential to make comparison between two types of companies. In addition, both large and experienced and small firms will be included in the samples because they are expected to behave differently. Regarding case screening, it should be noted that conducting R&D abroad for Taiwanese firms during the period of this study around year 2000 was not popular. There was not much related information available. Thus, the investigator needs to consult with experts from different fields such as industrial practitioners and gather data from various information channels such as commercial databases, corporate annual reports, governmental service agencies, etc. Eventually, eight Taiwanese companies with overseas R&D units were studied herein (see Table 1). The CEOs, top managers, R&D directors, and international product managers of these companies were interviewed. The companies sampled herein were mainly from two industrial sectors, computer hardware and computer software, and four companies were selected from each sector. Taiwan's computer industry is actually ranked in the top four in the world in terms of output, and thus has significant demand and opportunity for overseas markets and product developments. On the other hand, Taiwan's software industry is only just starting to boom, encouraged by the Stock Securities Commission relaxing listing rules several years ago, making it easier for software companies to go public and raise funds for further development.

Table 1　Background of Taiwanese companies in the sample

	Trend Micro	Bauer Software	Datasum Software	HannStar Software	Advantech Electronics	Primax Electronics	Unitech Electronics	Delta Electronics
Year established	1998	1993	1992	1997	1981	1984	1979	1971
Sales (million US$, 2003)	450	45	25	20	340	400	350	4000
Major product lines	Antivirus Software for PC, Server, & Internet Gateway	Educational Software	Business Software	CAI; Educational Software	Industrial Computer & Server	Imaging Products; Computer Peripheral; Paper Handling Equipment	Personal Computer	Power System; Power Supply to PC, Server; UPS etc.
Locations of overseas R&D Units	U.S., Japan, Philippines, China, India	the U.S.	China	the U.S.	the U.S., China	the U.S., China	the U.S., China	the U.S., the U.K, China, Thailand, Hong Kong

(TO BE CONTINUED ON NEXT PAGE)

| 備　　註 | 試　題　隨　卷　繳　交 |

| 考 試 科 目 | 管理文獻評析 | 所　別 | 科技管理研究所 | 考 試 時 間 | 5 月 21 日（六）第 1,2 節 |

4 Results and discussion

The following section presents and discusses the research findings, drawn mainly from the case studies. The presentation is based on the major constructs shown in the research framework.

4.1 The motivations and organization for global R&D

Regarding the locations of overseas R&D units, this study found that seven out of the eight companies sampled have R&D organizations in the United States (see Table 1). Many of the respondents mentioned that the U.S. market is quite important to them, leading them to establish R&D centres there to respond to the market there more quickly. For Trend Micro, one of the major purposes of building R&D units in the U.S. was to be close to the huge U.S. market. A high percentage of this market needs anti-virus software for server instead of that for PC as in Taiwan. Meanwhile, Delta Electronics has located one of its R&D units in Oregon in the U.S. to serve its major client Intel. The other important reasons for locating R&D centres in the U.S. are the ample pool of high quality technical and creative personnel available there. The quality workforce allows firms to leverage the resources for advanced R&D at which they may not excel. This motivation applies particularly for software and multimedia companies, which rely on U.S. counterparts for creative ideas and script generation in the early stage of software development. Taiwanese units then assume the subsequent development work, including programming, testing and so on.

Six out of the eight companies sampled herein also have R&D units in China. Many Taiwanese firms select China as a location for overseas R&D because of low labour costs and the shared linguistic and cultural ties there. Two of the software companies in the sample conducted planning and script generation in Taiwan, while leaving programming and testing to the R&D team in China. The labour is divided in this way because the latter tasks are basically labour-intensive. Surprisingly, only one company, Primax Electronics, set up a R&D unit in China mainly for supporting production activities. Several firms set up R&D units for advanced research around Beijing and Shanghai in China due to the availability of low-cost and highly sophisticated scientists and engineers.

Regarding the organization of trans-national R&D activities, only Trend Micro and Delta Electronics organize their overseas R&D activities according to product lines and business units. The remaining six companies sampled conducted trans-national research activities as collaborative "projects", with labour divided between Taiwanese and overseas R&D units. In most of the cases studied, the major decision-making authority for decisions regarding trans-national technological innovation and product development is the home country, Taiwan.

4.2 Technological strategy for global R&D

Among the eight companies sampled, Trend Micro appears to be the major firm that emphasizes a technological strategy for the globalisation of R&D. The corporation's president is a typical entrepreneur and wants his company to be the leader in the area of antivirus software. Thus, the company takes an independent approach to developing the necessary technologies. Trend Micro's strategy is to search for anything related to antivirus software with market potential. The president controls the organization, and plays a 'gatekeeper' role. The antivirus system is mainly (TO BE CONTINUED ON NEXT PAGE)

composed of user interface, database and module. The first item can differ from country to country owing to cultural and language differences. However, the latter two items could be fixed and embedded in a wide range of products. In fact, they can be built-up to become the core competence of the corporation. Trend Micro uses R&D resources in the U.S., Japan, and Taiwan to respond to local demand. Meanwhile, the company leverages its worldwide R&D resources to build its core competence through the integration of collection, analysis and data mining of viruses from all over the world. The company has thus consistently ranked number one in the anti-virus software sector by the Gartner Research Corporation of the U.S.

Meanwhile, Unitech Electronics holds a global meeting annually, attended by all of the top managers of its worldwide subsidiaries. The first aim of this meeting is to determine future technologies and products with potential. The managers then consider whether the necessary technologies could be obtained through either licensing-in from other sources, independent development, or strategic alliances. If independent development is chosen, the next step is to consider the division of labour between the Taiwan and overseas R&D units. Finally, Delta Electronics has constructed an R&D centre for advanced research at Raleigh to leverage the expertise of Virginia Polytechnic Institute and State University in power-related research.

Concerning the acquisition of technologies from other sources, some of companies studied even utilize the M&A (merger and acquisition) approach. Trend Micro acquired a Japanese firm and quickly obtained R&D personnel and distribution channels in Japan. Similarly, Delta Electronics acquired a Hong Kong company and gained access to professional notebook-PC-related power supply designers.

4.3 Managing global innovation process

As a firm becomes increasingly exposed to overseas markets and environments, the company would naturally show more interest in globalizing technological and R&D activities. Most of the companies studied, such as Unitech Electronics, Trend Micro and HannStar, cooperated with multinational corporations (MNCs) through OEM (original equipment manufacturer) and ODM (original design manufacturer) arrangements in their initial organizational development. These companies not only learned and upgraded their technological capabilities but also absorbed managerial skills from the MNCs. Firms conducting ODM business, usually have to build internal R&D units to be capable of designing what clients request. As both the domestic and overseas markets continue to grow, companies started to consider setting up R&D units abroad to either serve the market effectively or upgrade their technological capabilities.

Regarding the management of global R&D activities, this study found that larger companies, such as Trend Micro and Delta Electronics, tend to use product managers to coordinate trans-national R&D activities. This practice may arise because the organization is mainly based on product lines or business units. Meanwhile, the product managers themselves are in charge of the development of products for the whole overseas subsidiary. The product manager may also sometimes contact personnel with other functions from the home country. However, the purpose of this contact is to integrate other functionalities, not for R&D itself. The other six companies in the sample conduct their trans-national R&D activities through cooperation between the project managers from the home country and overseas. This type of collaboration is particularly notable in the development of software. For companies with overseas R&D units in the U.S., pre-production and script generation are first completed there, and the overseas project manager then goes to Taiwan for detailed discussions, normally lasting about three weeks. The Taiwanese

| 考　試　科　目 | 管理文獻評析 | 所　　別 | 科技管理研究所 | 考　試　時　間 | 5 月 21 日（六）第 1,2　節 |

project manager is in charge of programming and testing.　A similar interaction can be found between Taiwan and China: the project manager in Taiwan takes charge of planning and creative script generation, the project manager in China oversees the programming and testing. In the case of hardware companies, the Taiwanese project manager dominates the decision-making regarding trans-national R&D activities.

4.4 Communications in global R&D

Academics have indicated that communication, culture and language are some of the important influences on the performance of trans-national R&D activities [24]. Many respondents in the study did mention the importance of the aforementioned factors. Two respondents noted that the NIH (not-invented-here) syndrome was made even worse by the globalisation of R&D activities, despite R&D people belonging to the same company. Indeed, most of the companies are working hard to resolve the problems and to reduce international communication barriers.

Unitech and Delta Electronics are developing standard manuals and guidelines for global product innovation. Based on their experiences, these companies think the complex process of cross-national product development can be made smoother by adopting consistent procedures. Delta Electronics itself has even assigned several senior personnel as international liaison officers for coordinating trans-national R&D activities. As for the language problem, some of the firms studied used English as the language for communicating with overseas R&D units. Additionally, a few companies require that project managers have excellent language capabilities for international R&D activities. Meanwhile, several corporations preferred to recruit technical professionals with roots in either Taiwan or China to reduce barriers from communication and cultural differences.

Regarding the use of information-communication technology (ICT), most of the firms studied herein employ various tools to increase the effectiveness of global communication.　Normally, telephone, fax and/or e-mail are used to communicate with technical people overseas.　However, for some products, particularly hardware design, video conferencing or electronic bulletin boards are used for enhanced visualization and thus better communication.　In cases where the discussion needs simultaneous inputs from internationally dispersed technical groups, the companies adopt groupware for global group meetings. Unitech Electronics introduced a database management system for managing global product innovations, including developing product module for configuration.　The system helps Unitech to integrate its worldwide R&D activities so that once a specification changes in one location, other locations will immediately be notified.　Meanwhile, Trend Micro set up a sophisticated database system to collect worldwide information about computer viruses and eventually build its core competence. (TO BE CONTINUED ON NEXT PAGE)

| 備　　　　註 | 試　題　隨　卷　繳　交 |

考　試　科　目	管理文獻評析	所　　別	科技管理研究所	考 試 時 間	5 月 21 日（六）第 1, 2　節

問題一、何以「研發創新國際化/全球化」的重要性越來越高？（外國）企業在這方面的佈局/組織方式可能有哪幾種？各分別有哪些主要的考量？我國的情形又如何？與先進國家跨國企業比較起來可能有哪些異同？（25分）

問題二、企業應如何管理跨國研發創新？資訊硬體公司與軟體公司在這方面的異同點為何？
（20分）

問題三、很多企業經理人與政府官員強調「研發創新要根留台灣」，並提出「台灣研發、大陸生產製造」的概念。請問：此概念是否會有哪些可能的盲點？你自己進一步的看法為何？（15分）

問題四、請用類似「文獻回顧/批判」的方式來「回顧/論述/批判」此篇論文。
（15分）

問題五、請依你上述的論述/批判，提出新的、下一步的「研究計畫書(Proposal)」（包括：研究背景與問題、扼要文獻與學理論述、觀念（研究）架構、研究設計與方法等）。（25分）

備　　　　　註	試 題 隨 卷 繳 交