中 文 摘 要

科學認識觀在科學教育領域中一直被許多學者認為其會影養學生科學學習的歷程。同時，當學生在網路學習環境中進行科學學習相關活動時，也會使用不同的策略與標準來尋找並評判網路上所呈現出的科學相關訊息。本研究利用「科學認識觀點」及「網路訊息評判標準」問卷探討台灣高中學生對於科學知識所持有的認識論觀點及網路訊息評判的標準，並利用「網路導覽流程圖」方法來觀察和分析高中學生如何在開放式網路環境中搜尋相關資料以完成科學相關任務的學習歷程，進一步地探討學生所持有的科學認識觀點、網路訊息評判標準及搜尋策略對於其在網路環境中科學學習成效的影響。經由分析 62 位台灣高中生樣本，研究結果發現台灣高中學生所持有的科學認識觀、網路訊息評判標準與搜尋策略對於網路環境中的科學學習成效具有顯著的關聯性。而在具有時間限制的網路科學學習活動中，利用較多時間來瀏覽特定網頁內容的學生表現出較佳的學習成效。此外，研究結果中發現台灣高中學生同時會持有不同組合的科學認識觀點與網路搜尋評判標準，而科學認識觀點與網路搜尋評判標準間具有顯著的關聯性。再者，迴歸分析的結果進一步地發現具有建構主義取向的科學認識觀與適切的網路訊息評判標準的學生，在網際網路學習環境下表現出較佳的科學學習成效。因此，研究者認為在網路學習環境中除了必須重視學生認知與後設認知學習策略的發展外，同時也必須進一步地瞭解學生所持有的認識觀點。本研究建議在未來網路環境，尤其是在開放式的網路學習環境下，除了協助學生發展合適的搜尋策略外，更必須瞭解學生的科學認識觀點並在其融合在以網路為基礎的科學相關學習活動設計與發展中，讓學生透過網路學習環境下的科學學習活動中發展出建構式取向的科學認識觀。

關鍵詞：科學認識觀、網路科學訊息、搜尋策略、網路導覽流程圖、網路訊息評判標準、科學學習

Abstract

This study was conducted to explore the interrelationships between students' scientific epistemological views, information commitments, searching strategies and Internet-based science learning performances. Two self-reporting questionnaires, direct observations and in-depth interviews were employed to collect both quantitative and qualitative data. Through analyzing 62 Taiwanese high school students' questionnaire responses, coding of direct observations and interview results, the following findings were revealed. High school students' scientific epistemological views, information commitments, searching strategies, in some ways, were significantly related to the Internet-based science learning performances. In an Internet-based science learning activity with time constraint, female students spent more time on inspecting the content of Webpages than males and acquired better science learning performance. Both quantitative and qualitative results showed that students possessed different combinations of scientific epistemological scientific views or information commitments to deal with the encountering information on the Internet;and, some of students' scientific epistemological views were significantly related to their information commitments. The results of regression analysis indicated that some of students' information commitments could predict their Internet-science learning performances. Further, students having constructivist-oriented views toward science and proper information commitments may perform better than the others with empiricist-oriented views and inappropriate commitments. Consequently, the findings in this study revealed the importance of scientific epistemological views, information commitments and searching strategies in the open-ended online science learning activities. In addition to enhancing student' searching strategies, the design of the Internet-based learning environments may not only include cognitive and metacognitive developments, but also address the concerns

of epistemologies in the future.

Keywords: scientific epistemological views; information commitments; information searching; navigation flow map; Web-based learning; science learning; information processing.

誌 謝

在就讀研究所的這三年裡，無論是在學業研究或是家庭生活上，都充滿了許多辛苦與甜美的記憶。而過程中也有著許多人的幫助與體諒，著實令我感到相當多的溫暖與鼓勵。也因為如此，我才能順利地完成人生中一個重要的階段。

首先，我必須感謝我的指導教授蔡今中博士。無論是在學術研究或待人處事上，他都是一個最值得我學習並遵循的典範。他的寬容、尊重與付出，也讓我往往因為本身資質的愚拙，無法在研究上有著相等的回應而感到萬分的愧疚。然而，不管是在生活或是論文研究上，他依然一直給予我最大的空間和及時的協助，來支持並鼓勵我論文及相關研究的完成。此等亦師亦友的情誼，實為我人生中最珍貴難得的緣分，讓我心中對老師充滿感激之意。我也要感謝張俊彥教授、楊芳瑩教授及蔡孟蓉教授，三位老師除了細心地審視我的論文，且不吝提出他們許多寶貴的建議，來彌補論文中許多缺失而使我的碩士論文能更加的完善。

感謝研究所的同學，姿津、 婭妏給在我學業及生活上遇到挫折時，總能適時地傾聽並給予鼓勵。感謝許多研究夥伴，學長穎洄、鴻銘、旻憲、助理雅怡等，尤其是學長無論在研究或是生活上都給予我相當多的鼓勵與協助，而其他夥伴們的關心，也都讓我感受到家人般的溫暖。有你/妳們真好！！

感謝父母親的鼓勵及岳父岳母在生活上的照顧與關心。此外，一路上支持我的朋友，昭淵、欽文、正義等，你們總是提供我生活上的協助並陪伴我度過許多艱困的時刻。好朋友，謝謝你們。最後，我特別要感謝我的太太紹華，在我論文寫作的最後一年，願意放下工作來照顧女兒涵煦及我的生活。她的犧牲、寬容與付出是最令我感動與不捨的，而她全心全意的支持，也讓我能無後顧之憂地進行論文的研究。女兒涵煦的成長與笑容，也是我能持續下去的動力。紹華及涵煦，妳們成就了我，謝謝。在此希望我的論文對國內的科學教育能有一點貢獻，往後也期許自己能在教育領域中的相關研究能再有所精進。謝謝大家一路上的幫助，在此祝福關心我的大家平安順利。

List of Tables

List of Figures

Chapter 1 - Introduction

1.1 Origin of the study

During the 20th century, the advancements of technologies have really made a great impact on the reform of science education, and gradually changed the way of instruction and students' learning science (Chiu, 2002; Linn, 2003; Mistler-Jackson & Songer, 2000). The growing role of technology in science and other disciplines has engaged educators and researchers in developing professional systems to help teachers develop suitable instruction and scaffold students' learning activities (Linn, 2000; Linn, Clark, & Slotta, 2003) by incorporating Internet materials into formal instruction (Ruthven, Hennessy and Deaney, 2005; Skinner and Preece, 2003). Besides, other studies made efforts to investigate benefits that technologies may contribute to students' learning science (Hoffman, Wu, Krajcik and Soloway, 2003; Tsai, Lin and Yuan, 2000, 2001a). Numerous studies have recognized that educational technologies may be taken as powerful tools and potential ways to assist students' knowledge construction, development of cognition, and learning strategies (Chang, Sung and Chen, 2001; Chiu, Huang and Chang, 2000; Wen, Tsai, Lin and Chuang, 2004).

Especially, as the growth of communication technologies (e.g., Internet), the increasing and convenient access to information has amplified the opportunities for students' science learning, supported the reforms of science instruction, and extended the scope of science education research (Linn, 2003; Mistler-Jackson & Songer, 2000; Tsai and Tsai, 2003). Most students view Internet as an effective way to search relevant information for answering specific questions or fulfilling their academic needs (Voorbij, 1999), as well as numerous teachers employ searching and usage of

Web information as a major method to enrich science learning and instruction (Lin &Tsai, 2004; Tsai & Tsai, 2003). The suggestion that students having advanced on-line searching and evaluating strategies may develop more accurate and in-depth understandings for certain topics has been pointed out in previous research literatures (Hess, 1999; Hill, 1999; Hoffman, Wu, Krajcik & Soloway, 2003; Oliver and Hannafins, 2000; Tsai & Tsai, 2003). There is another critical concern. That is, while searching information on the Web, what are standards students utilize to judge a variety of information on the Web and how these standards assist students in filtering information to fulfill their purposes? These aspects and assumptions are all related to the theory of epistemology which accounts for one's knowledge construction.

Although previous studies related to Internet-based instruction has begun considering design principles about users' epistemological underpinnings of science and integrating these aspects into specific projects (Chou & Tsai, 2002; Tsai, 2001a), they rarely elaborated the interrelationships on how epistemological beliefs influence students' learning activities in the Internet-based learning environments. The epistemological beliefs students possessed and employed may form another type of evaluative standards when engaging in Internet-based learning environments. For example, Tsai (2004b) proposed a framework for information commitments to describe students' evaluative standards when processing the materials on the Internet. These standards help students filter and select information on the Web, and he also asserted that information commitments are possibly related to students' epistemological beliefs involving judgments and perceptions about the nature and merits of knowledge or information from the Internet.

Most researchers have recognized that the Internet can be used as both cognitive and metacognitive tools to foster development of students' cognition structure (Hofer, 2004; Jonassen, 2000; Tsai, 2001b, 2004a; Wen, Tsai, Lin and Chuang, 2004). Further, Tsai (2004a) asserted that the Internet could be not only used as a cognitive or metacognitive tool, but also an epistemological tool for instruction which encouraged students to evaluate the merits of information and knowledge acquired from Internet-based environments, and to explore the nature of learning and knowledge construction. That is, incorporating epistemological awareness into Internet-based learning activities could be used to promote students' ability to think critically when searching and evaluating information on the Internet.

Hofer (2004) addressed a need to be conscious about how students evaluate information on the Web, integrate information into existing theory, and produce their own knowledge assumptions. As Clark (1983) claimed that technologies are merely instruments delivering instructions, but do not entirely substitute the function of teaching and learning or promote students' learning outcome by the technologies themselves. Also, the following description the role of technologies on students' learning activities by Jonassen, Howlan, Moore, and Marra (2003) let us reconsider the way that technologies themselves can bring about effective influences on students' learning.

> The ways that we use technologies in schools should change from technology-as-teacher to technology-as-partner in the learning process. Students do not learn from technology, they learn from thinking. Technologies can engage and support thinking when students learn *with* technology……students learn *from* technology what the technology knows or has been taught, just as they learn from the teacher what the teacher knows. (pp. 11-12)

These assertions broken the misconceptions that technologies could account for students' knowledge construction, development of cognition and beliefs, advanced learning strategies, and learning achievement. On the contrary, increasing studies started addressing students' individual differences (e.g., epistemological beliefs and leaning strategies) when engaging in technology-based learning environments. That is, the focuses of technology-related issues have turned to explore the interaction between students' learning and technology-based learning environments, as well as what factors can facilitate students to learn effectively and meaningfully in the technology-assisted learning environments.

Are students ready for involving in an Internet-based learning environment? How students find relevant information they want on the Internet? Are students capable of dealing with the complexities of Web information? Can students' epistemological beliefs serve as a filter when facing Web materials? Few earlier studies have clearly responded to these questions. However, when learning setting has been turned from traditional instructions into Internet-based environments, students must take more responsibility for searching and evaluating information needed to solve problem (Jonassen et al, 2003). Hence, a careful examination for answering aforementioned questions is needed to interpret what and how students process information on the Internet.

1.2 Purposes of the present study

First, the main purpose of this study was to investigate students' online searching behaviors by observing navigation traces, to reveal their searching strategies, and a new method 'Navigation flow map' was proposed. Second, we try to understand whether the role of epistemology-related issues stand a crucial position in the Internet-based learning activities, which may guide students to filter information on the Web. Finally, based upon the results of navigation flow map and further comparison with response of epistemological beliefs, we intended to clarify the interactions between students' epistemological beliefs, online searching behaviors and Internet-based learning outcomes which may help researchers understand how to facilitate students' effective learning in the Internet-based learning activities.

1.3 Research questions

Corresponding to the purposes of research, the present study attempted to explore several questions as following:

1. What types of strategies high school students employed when searching relevant information to perform science-related task on the Internet? Are there differences existing among students' online searching strategies?
2. What kind of standards (i.e., information commitments and scientific epistemological beliefs) students possessed when facing a variety of information on the Internet?
3. What are the relationships between students' online searching strategies, epistemological beliefs (i.e., information commitments, scientific epistemological views) and Internet-based learning outcomes?

By trying to answer questions above, this study is intended to explore and correlate students' internal philosophical concerns about knowledge (e.g., epistemological beliefs) with their learning strategies (e.g., online searching strategies). In addition, by exploring the relationships between students' epistemological beliefs, online searching strategies, and Internet-based performance outcomes, educators could know more about role of students' epistemological beliefs which may influence their learning strategies and learning outcomes in the Internet-based learning environments.

Chapter 2 - Literature review

Due to the widespread applications of the Internet technology on science education, it is necessary to investigate its influences on students' science learning based upon different facets. Previous findings suggested that Internet-related learning activities could promote students' knowledge acquisition, cognitive engagement and learning performance (Lin, 2000; Tsai, 2001b; Tsai & Tsai, 2003). That is, when students engaged in Internet-based learning environments, Internet technologies are not merely tools delivering and presenting information, but treated as a powerful way to help students construct knowledge and reinforce cognitive structures.

This chapter intended to describe the trends of Internet technologies for science instruction and then illustrate some key factors that may determine students' effective learning in the Internet-based learning activities. Some suggestions and hypotheses were summarized for the research design in the present study.

2.1 Learning science on the Internet

With the innovation of the Internet technologies, various on-line resources can be easily acquired to enrich content of subject and assist teaching practice as well as facilitate students' learning. The advantages of Internet technologies really reshape the instruction, practice and learning in science education. Research findings also showed the positive effects of Internet technologies which may contribute to students' science learning (e.g., Mistler-Jackson & Songer, 2000; Ng & Gunstone, 2002; Rivet & Krajcik, 2004; Tsai & Tsai, 2003).

In this section, an attempt was made to emphasize the emergence of Internet-based learning activities regarding science and the influences on students' science learning. The present study tried to introduce both well-designed and open-ended online resources for learning science, and explore its influences on students' Internet-based science learning.

2.1.1 Well-designed online resources for science learning

Recently, many studies have discussed the incorporation of Internet technologies into science lessons and the integration of Internet technologies with well-arranged instructional strategies to help student learn science (e.g., Fisher, Troendle and Mandl, 2003; Lumpe and Butler, 2002; Recker, Dorward and Nelson, 2004; Ruthven, Hennessy and Deaney, 2005; Skinner and Preece, 2003). For example, Ruthven *et al.* (2005) conducted five Internet-assisted projects across different subjects, which incorporated online resources into instructional practice to support the study of science topics. The result showed that Internet-based science learning project promoted more active student participation, multiple information sources, and critical synthesis. In addition, in the Internet-based learning environments, the role of teacher has been turned from traditional instructor into assisting tutor.

Lin, Clark and Slotta (2003) also conducted an Internet-based learning project, the Web-based Inquiry Science Environment (WISE), to provide designers a technology-enhanced, research-based, flexibly adaptive learning environment. Integrating features such as visualization, simulation, collaboration and representation into the WISE, teachers can combine Internet technologies with successful experiences in traditional learning environments and create suitable science curriculum projects via WISE. The WISE can be combined with other learning environments in different forms of instruction to expand the application of WISE inquiry projects which can promote students' critical thinking and inquiry-oriented learning. However, there were no empirical reports about the influences of the WISE on students' Internet-based science learning outcomes.

Based upon the merits of the Internet technology, many studies developed online concept mapping system to promote students' development of conceptions on science, probe students' alternative conceptions toward science, and evaluate their learning outcomes on science (Chiu, Huang & Chang, 2000; Tsai, Lin & Yuan, 2001a). Concept mapping is an effective instrument proposed by Novak and Gowin (1984), which is designed to summarize concepts learned and their interrelations. Tsai *et al*. (2001a) developed a Web-based concept map test (WCOMT) to analyze students' exercises and strategies for science learning. The findings above two studies revealed that students with more critical thinking, metacognitive self-regulation abilities are more likely to use and benefit from the online test system. It also showed that Web-based concept mapping systems can promote students' interactive, collaborative, learner-centered approaches when engaging in the Internet-based learning environments to learn science.

Many science learning activities based on the advantages of Internet have been arranged for students to learn scientific concepts. Previous literatures also supported that Internet-based learning environments may advance the progress of science instruction and learning. However, the ease of access to online information being mostly out of preparing for learning science, students may increasingly face with unimaginable quantity and variety of sources on the Internet. Thus, students may need proper strategies to find relevant resources on the open-ended Internet-based learning environments.

2.1.2 Searching open-ended online resources for science learning

By contrast to well-structured online learning activities, an open-ended Internet learning environment seems to be more ill-structured. All kinds of information resources and communication templates emerge from the Internet to fulfill multiple needs of online users and participants. It may expose students to some risks of failure of learning when students utilize Internet as learning sources for enriching the quality and quantity of learning activities. Thus, researchers and educators must consider individual capabilities such as searching strategies when preparing students for entering such open-ended online learning environment.

Tsai and Tsai (2003) scheduled eight college students to perform a Web-based science-learning task which intended to acquire basic concepts of nuclear power and the usage of nuclear power in Taiwan by searching for related knowledge and information on the WWW. By protocol analysis and observations of searching behaviors, they proposed a set of criteria to describe participants' searching actions and moves: Control, Disorientation, Trial and error, Problem solving, Purposeful thinking, Selecting main ideas, Evaluating information, being categorized into three domains as Behavioural, Procedural and Metacognitive. Additionally, they examined the influences of students' Internet self-efficacy on these online searching strategies. The findings revealed that students with high Internet self-efficacy display more advanced online searching strategies than those with low Internet self-efficacy when engaging in Web-based science learning activities. Through comparison between pre- and post-test, students with more advanced online searching strategies also showed obvious progression of learning achievement than those with less advanced online searching strategies

Similarly, Lin and Tsai (2005) conducted different Internet-based learning activities to acquire more clear views about students' online searching strategies and further proposed a novel methodology, called as 'Navigation flow map', to investigate students' online searching behaviors when proceeding science learning activities on the Internet, and their online searching strategies while facing complex information sources on the WWW. The study revealed that students showed various online searching strategies categorized as 'Exploration', 'Mixed', and 'Match'. Participants in 'Exploration' group selected more multiple resources to complete tasks and attained better performance. Additionally, students with different majors (e.g, science versus social studies) employed different online searching strategies to complete tasks and attained different performances on Internet-based learning activities.

It was supposed that students with more sophisticated searching strategies may be more capable of searching relevant information to support some learning activities involving the open-ended Internet resources. In other words, except well-designed learning projects and basic skills of computer operation, it is needed to address students' searching strategies when encountering unlimited materials and information on the Internet.

2.1.3 Summary and implications

By synthesizing Internet-based science learning activities described above, the present study summarizes some features about Internet-based science learning activities. The major differences between well-structured and ill-structured learning activities on the Internet are the pre-filtration of learning materials and additional guidance of learning. In other words, in the well-structured Internet-based learning environments, teachers or designers are used to pre-select and decide what subjects or materials that students have to learn from the Internet. Although such well-designed programs provided unique functions for assisting students' science learning, students may be still in a traditional learning environment in which teachers feed students with refined resources.

Previous research suggested that Web-based learning activities should include explicit subjects, coherent contents and well-arranged sequence to assist students in learning (Chou and Tsai, 2002; Linn, 2003). However, for the most part, students may participate in the ill-structured Internet learning environments in the school settings or at home actually. Unless students selected particular courses involving those well-designed online learning systems, they have limited opportunities to learn science in these professional interfaces or systems. That is, when incorporating Internet resources into formal curricula for students' science learning, researchers and instructors must concern about the basic requirements in which students should employ as standards or skills to monitor their learning on the Internet.

2.2 Personal epistemological beliefs

Personal epistemology is mainly concerned with what and how individuals perceive the nature of knowledge construction. Numerous studies were devoted to the understanding about influences of personal epistemology on students' learning. It has been recognized that epistemology-related conceptions can be a critical and powerful variable to predict students' learning activities and achievements in different fields (Chan and Sachs, 2001; Davis, 2003).

This section describes the current issues of epistemological beliefs and illustrates their influences on students' learning. In addition, this section further emphasizes the role of epistemology to deal with complex sources of knowledge (e.g., multiple information on the Internet) for acquiring a better understanding its influences on Internet-based learning.

2.2.1 Psychologists' perspectives about epistemological beliefs

The terminology of 'epistemology' is originated from the field of philosophy, and it is related to human knowledge. Philosophers used epistemology to present individuals' conceptions about the nature of knowledge. By contrast to the perspectives of philosophy about epistemology, psychologists pay more attention to how the individuals' conceptions toward knowledge and knowing grow and develop. Recently, numerous educational psychologists have recognized that epistemological beliefs not only interpret the conceptions toward the nature of knowledge, but also involve the awareness of processes of knowledge construction (Hofer, 2000, 2001; Hofer and Pintrich, 1997). That is, when investigating students' epistemological beliefs, researchers must consider both two parts of epistemological beliefs as knowledge and knowing. In other words, psychologists view individuals' epistemological beliefs as dynamic than static.

In order to illustrate the structure of epistemological beliefs, researchers conducted various frameworks to interpret components of epistemology. As opposed to previous aspects which viewed epistemology as uni-dimension, numerous studies proposed that individuals' epistemological views toward knowledge and knowing are multi-dimensional (Buehl and Alexander, 2001, 2002; Hofer, 2000; Hofer and Pintrich, 1997). By reviewing epistemology-related literatures, Hofer and Pintrich (1997) proposed four underlying dimensions about knowledge (i.e., certainty of knowledge, simplicity of knowledge) and knowing (i.e., source of knowledge and justification for knowing). One may display diverse perspectives on these dimensions to present their conceptions toward the nature of knowledge and ways of knowing. It has been recognized that epistemological beliefs are related to students' ways of learning, reasoning and judgment (Hofer, 2001; King and Kitchener, 2004). In other words, people may make judgments and decisions about controversial issues throughout the epistemological beliefs they hold.

By reviewing previous literatures of students' epistemological beliefs, students may hold some general beliefs toward knowledge across domains (Schommer and Walker, 1995) or differ across domains at different levels of education (Muis, 2004). That is, beliefs of students majoring in one domain may differ from those majoring in another domain; or, students m may have different beliefs toward domains. In other words, both general and specific epistemological beliefs may exist simultaneously to help students evaluate encountering information on different settings. For example, students may employ domain-general beliefs to judge unfamiliar information, whereas evaluate subject-related (between or within) materials based upon their domain-specific beliefs. However, as students develop domain-general or -specific beliefs to evaluate academic knowledge and learning, it can be queried whether these standards function identically in other learning environments (such as Internet-based learning environments). Tsai (2004b) proposed the idea of information commitments which are involved in the field of epistemology to account for students' standards of judgment in facing complicated information on the Internet. Hence, it can be suggested that one may develop different kinds of standards based upon their epistemologies to evaluate and judge various materials in different learning environments.

2.2.2 The constructivist epistemology

In general, philosophers focused on the nature and justification of common human knowledge. Instead of considering the truth and correctness of human knowledge, an important recent of philosophical epistemology is constructivism which emphasizes that knowledge construction is created by individuals (von Glasersfeld, 1989, 1993), interacted with society (Solomon, 1987) and depended on various contexts (Cobern, 1993). It mainly emphasize individuals' active role to construct one's own knowledge based upon their prior knowledge (Wanderse, Mintzes & Novak, 1994)

Especially in the field of science education, it has been recognized that the constructivist epistemology has made a great impact on science teaching and learning (Matthews, 2002). Numerous studies has evidenced that constructivist epistemology can contribute to students' science learning (Tsai, 1998a, 1998b, 1998c, 2000). It also shows that students' epistemological views about science are related to their epistemological beliefs about knowledge and knowing (Tsai, 1998a, 1998b, 1998c). However, by contrasting to the empiricist epistemology, constructivist epistemology showed diverse approaches to science instruction and learning. For example, students with empiricist-oriented epistemological views may view the purpose of learning as simply acquiring a collection of facts, whereas students with constructivist-oriented epistemological views tended to cope with experiences related to their prior knowledge as their learning goals.

2.2.3 Epistemological beliefs toward science

Researchers and institutions of science education view students' understandings about the nature of science as a critical part of scientific literacy (American Association for the Advancement of Science [AAAS], 1990; National Research Council [NRC], 1996). Helping students develop advanced conceptions about the nature of science has also been a major purpose for kindergarten through Grade 12 (K-12) science education (Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). Numerous research findings also support that one's better understandings about the nature of science help their processing of scientific information, learning orientations and attitudes toward science (Tsai, 1998a, 1998b, 1998c).

2.2.3.1 Epistemological views of science

As previous description that individuals may develop specific epistemological beliefs across domains, nature of science (NOS) was used to present students' epistemological views toward science in science education. Most students who held naïve views about the nature of science (such as empiricist views) may deem that scientific knowledge can be passively acquired, and limited to observing rather than constructed by own explanations (Carey, Evans, Honda, Jay and Unger, 1989). Hence, these students may employ rote memorization rather than other meaningful learning strategies to learn scientific knowledge (Tsai, 1998a).

Through investigating open-ended questionnaire and in-depth interviews of fourteen preservice science teachers, Abd-El-Khalick, Bell and Lederman (1998) proposed three facets of the NOS: *The empirical basis and tentativeness of science, Subjectivity and creativity in science, Theoretical constructs in science.* These conceptions of the nature of science represent teachers' beliefs toward scientific knowledge, which may influence successful implementation of the reform efforts in the science classroom.

To make a better understanding of students' scientific epistemological beliefs, Tsai (1998c) employed both quantitative and qualitative methodologies to assess junior high school students in Taiwan. The responses of interview questions revealed that students with constructivist-oriented approaches viewed science as creative activity, stressed the tentativeness and uncertainty of scientific knowledge, believed the influences of scientific theory. The results showed that constructivist students may employ more meaningful learning strategies in learning science as following:

1. Explain to others to ensure understanding
2. Metacognitive skills to monitor the construction of ideas
3. Active approach to learning science

4. Use different methods to solve problems

Hence, students' scientific epistemological beliefs may determine the ways and then success of learning science.

Except for qualitative methods (e.g., open-ended questionnaire, in-depth interviews) or uni-dimensional manner to acquire understanding of teachers' or students' conceptions toward the nature of science (Lin, 1998; Promery, 1993), the aspects of multiple dimensions about the nature of science has been proposed (Tsai, 2004). In order to make a better understanding of students' scientific epistemological beliefs, by combining the qualitative and quantitative data analyses, Tsai and Liu (2005) proposed a multi-dimensional questionnaire to assess various dimensions of scientific epistemological views (SEVs) for high school students in Taiwan. The scientific epistemological views (SEVs) questionnaire involved five subscales: the role of social negotiation on science, the invented and creative reality of science, the theory-laden exploration of science, the cultural impacts on science, and the changing feature of science. From constructivist to empiricist view, the SEVs instrument can identify various dimensions of scientific epistemological beliefs and explore students' agreements toward the nature of science.

Research results supported that students with more constructivist-trended SEVs may produce superior science learning performance than those with empiricist-trended SEVs (Songer & Linn, 1991; Tsai, 1998b, 1998c, 2000). Moreover, students showed different patterns on the five dimensions of SEVs. Students with different types of patterns about SEVs may acquire benefits dissimilarly in different types of instruction (i.e., Internet-based learning). That is, it is needed to utilize multi-dimensional instrument to evaluate students' effectiveness of different types of science instruction.

2.2.3.2 Epistemological beliefs toward science learning

Instead of focusing on the nature of scientific knowledge, students' epistemological beliefs toward the construction of scientific knowledge (or beliefs about learning science) should be taken into account. That is, paralleling with the knowing of personal epistemological beliefs, we must consider that students' conceptions about how to learn scientific knowledge. Relevant literatures about conceptions of learning showed that students may possess various perceptions when learning in different educational contexts (Eklund-Myrskog, 1998; Maeshall, Summer and Woolnough, 1999; Marton, Dall'Alba and Beaty, 1993; Tsai, 2004).

As psychologists stressed the knowing as a critical part of epistemological beliefs which may differ across different domains, previous research showed that students' conceptions toward learning could be categorized as *Remembering (Memorizing), Understanding, Applying and seeing in a new way*. Tsai (2004) further investigated students' conceptions of learning regarding science. Through a phenomenographic analysis of students' interview transcripts, he identified seven different conceptions of learning science as memorizing, preparing for tests (testing), calculating and practicing tutorial problems, the increase of knowledge, applying, understanding, and seeing in a new way. Following aspects advocated by Marton *et al*. (1993, 1997), these seven conceptions can be categorized as quantitative views (memorizing, testing, calculating, increase) and qualitative views (applying, understanding, seeing in a new way). Students who possessed quantitative views may simply view learning science as how much learning materials is learned, whereas students with qualitative views may try to integrate and refine scientific knowledge and further extend it to other situations.

Hence, the importance of leading students to acquire qualitative views of learning (i.e., Understanding, Applying and Seeing in a new way) and understand what they learnt deserve more attention in educational research (Perry, 1970). Furthermore, what conceptions students held toward learning science may influence their forms of knowledge acquisition from reproducing to extending and developing (Tsai, 2004).

2.2.3.3 Summary and implications

The NOS not only represent one's conceptions about nature of scientific knowledge, but also awareness of science as a way of knowing and beliefs to the development of scientific knowledge (Abd-El-Khalick, Bell and Lederman, 1998). That is, linking up domain-specific aspect with personal epistemological beliefs about knowledge and knowing, students shall be aware of nature about scientific knowledge and conceptions of how to learn science effectively. For example, students who kept constructivist-oriented views about nature of science (i.e., tentativeness, autonomy) may adopt more meaningful learning strategies to develop coherent understandings of science concepts (Davis, 2003).

As aforementioned statements about the rise of Internet-assisted learning in science education, it may expose students to a quite different learning situation from traditional classrooms. Most previous studies have advocated employing the Internet to help students learn science and revealed its effectiveness on students' science learning (Lin, 200, 2003; Lin, Clark & Slotta, 2003; Mistler-Jackson & Songer, 2000; Tsai & Tsai, 2003). However, as epistemological beliefs shape some standards for evaluating knowledge, students may judge the merits of scientific knowledge on the Internet according to their conceptions of the nature of science and then develop corresponding conceptions of learning science to apply scientific knowledge. Hence, it may be important to investigate students' conceptions of NOS and its relation to learning science in the Internet-based environments.

2.3 Standards and skills for learning science on the Internet

What do students depend on when selecting, judging and filtering relevant information on the Internet and then acquiring the knowledge from the Internet-based learning environments? This section attempts to answer this question by illustrating the impacts of students' epistemological beliefs in the Internet-based learning activities, and proposes that the epistemological beliefs may shape some evaluative standards when dealing with Web information.

The features and influences of individuals' beliefs system have been broadly discussed and investigated in philosophical and psychological fields as described above. It revealed that individuals' beliefs might affect their subsequent behaviors, learning approach and processing of information when facing varied sources of knowledge (Tsai, 2001b, 2004a; Whitmire, 2003, 2004). In other words, exploring students' beliefs toward knowledge and knowing may provide educators more clear views about students' learning process, especially when they engage in a complicated setting such as Internet to acquire subject knowledge.

2.3.1 The role of epistemological beliefs on the Internet

The increasing opportunities for approaching the varieties and complexities of the information on the Internet bring students into a setting quite different from traditional learning environment. As students search and encounter new information on the Internet, their goals, needs and ways of learning may depend on the standards and beliefs toward the knowledge and knowing (Hofer, 2004). Synthesizing philosophical and psychological perspectives, epistemology is related to individual's views about the nature of knowledge, and the dynamic process about how knowledge is constructed and evaluated (Hofer & Pintrich, 1997). Hence, when accessing information and acquiring knowledge on the Internet, students may search, evaluate, clarify and integrate multiple sources of knowledge and transfer it into individual theory according to the standards of personal epistemology. Furthermore, it is necessary to consider specific information (e.g., science) presented on the Internet, which may require applying domain-specific epistemological beliefs (e.g., scientific epistemological beliefs) to handle particular materials on the Internet.

Students who hold advanced epistemological beliefs might realize the advantage of open-ended learning environments (e.g., Internet) and viewed sources of knowledge (e.g., Web information) as more dynamic and uncertain (Tsai, 2004b). Consequently, it is possible that students may extend particular standards to value Web information based on their epistemological beliefs. In order to illustrate how students judge information in the Internet-based learning environments, Tsai (2004b) proposed a theoretical framework for identifying 'Information commitments' intended to explore the principles students or teachers employ to select, evaluate and judge information on the Web. By interviewing ten college students and two experts, he categorized ‘Information commitments (ICs)’ into three dimensions: standards for correctness (ranging from ‘Multiple sources’ to’ Authority’), standards for usefulness (ranging from ‘Content’ to ‘Function’) and searching strategies (ranging from ‘Elaboration and exploration’ to ‘Match’). Results revealed that experts show more sophisticated orientations (e.g., multiple sources, content, elaboration and exploration) than students when dealing with Web information. Information commitments also are involved in the field of epistemologies, but mainly function as the standards for estimating the value of information on the Internet (Tsai, 2004c), as shown in Fig 2.1.

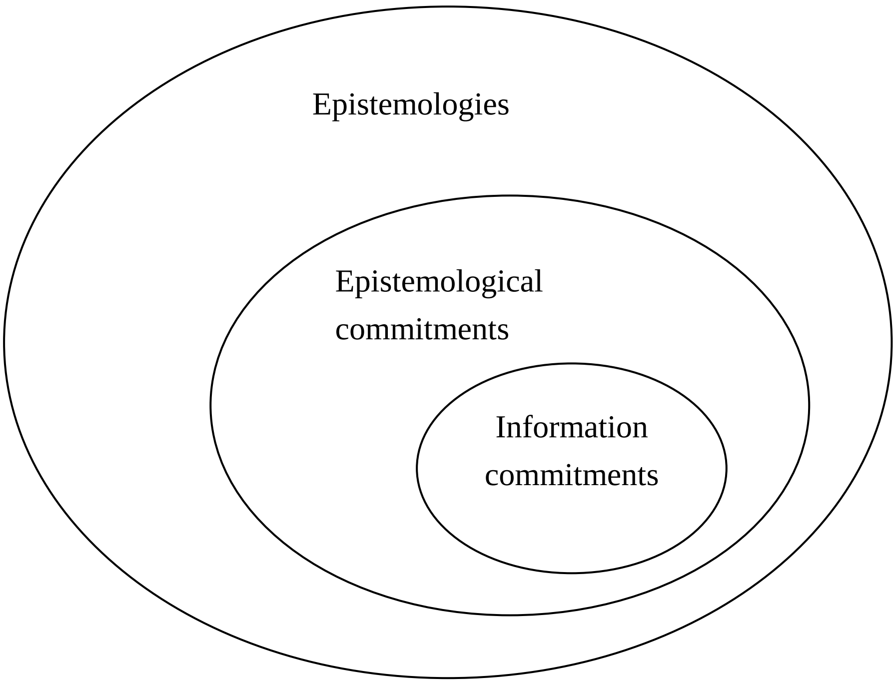


Fig 2.1. The relationships among Epistemologies, Epistemological commitments, and Information commitments (Cited from Tsai, 2004)

Based upon this perspective, Wu and Tsai (2005) further developed the Information Commitments Survey (ICs) to investigate a group of college and graduate students in Taiwan about their information commitments in the Web-based learning environments. The ICs survey was a six-point Likert scale (ranged from ‘strongly disagree' to 'strongly agree') and included six scales involving 'multiple sources as correctness', 'authority as correctness', 'content as usefulness', 'technical issues as usefulness', 'elaboration and exploration as searching strategy', and 'match as searching strategy'. The findings showed that students categorized as 'elaboration and exploration' searchers may express information commitments as 'multiple sources as correctness' and 'content as usefulness'. The study proposed some relationships between students' epistemological beliefs and online searching strategies.

In science teaching and learning, Internet has been viewed as an effective tool to assist students' acquisition and construction of information and knowledge. Today, we can easily find the relevant source of information and knowledge on the Internet to answer unfamiliar science-related issues. However, what standards do we base upon when handling specific form of information (e.g., science) on the Internet? As personal epistemologies play an important role of evaluating information and knowledge in general, scientific epistemological views particularly deal with the information and knowledge about science. It can be supposed that students who well understand the nature of science and possess advanced epistemological beliefs toward science would benefit greatly by engaging in science learning activities and develop more positive attitudes toward science (Tsai, 2004d).

Hence, students' scientific epistemological views may not only influence their standards of judging scientific information and knowledge, but also further contribute to their completion and performance of online science learning activities. Therefore, when Internet enters science classroom and provides resources of scientific information for science learning activities, students' scientific epistemological beliefs may service as standards for selecting, judging and integrating scientific information on the Internet. Consequently, scientific epistemological beliefs may shape a crucial part of guiding students' meaningful learning strategies to evaluate science-related information and learn scientific concepts effectively on the Internet.

Most of research findings revealed the impacts of epistemological beliefs, scientific epistemological beliefs on students' learning in the educational setting as previous description. However, there is still less attention on exploring interrelationship between epistemologies (both domain-general and domain-specific) and learning activities on the Internet. Hence, the present study is intended to investigate the position of epistemology-concerned perspectives in the Internet-based learning environments and its relation to Internet-based learning activities.

2.3.2 Searching strategies for Internet-based learning activities

In current stage, one of the major methods of implementing Web-based instruction involves the search and usage of Web information to enrich learning and instruction. As a result, learners' ability of seeking relevant information plays a crucial role in Web learning environments. In particular, most students often utilize some popular search engines (such as Google or Yahoo), which can be viewed as main entrances of information seeking on the Internet, to proceed their information seeking behaviors, and then further retrieve information from a relevant site to gain understandings for certain topics (Bilal, 2000, 2001,2002; Bilal & Kirby, 2002; Lazonder, 2000).

Information searching, distinguished from simply browsing or navigating, is a process in which people purposefully engage in to fulfill their needs for learning and problem solving (Marchionini, 1995). Many researchers have suggested that learners' information searching behaviors involve dynamic procedures of cognitive operations and information processing (e.g., Bilal, 2000, 2001, 2002; Bilal & Kirby, 2002). Investigating students' on-line searching process also gave researchers an insight into understanding the role of cognition influencing knowledge construction (Hofer, 2004). Moreover, it has been revealed that Web users' experiences with the usage of Web, information retrieval tools, domain knowledge, cognitive abilities and affective states, could contribute to the ways in which they seek information (Hsieh-Yee, 2001). In other words, searchers with different cognitive abilities, domain knowledge or Internet experiences may lead to various information searching strategies and patterns when they navigate on the Web. Hence, when exploring navigators' searching features and processes, it is important to consider searchers' background knowledge and relevant experiences.

Previous studies conducted various ways to explore Web users' searching behaviors. For example, Tabatabai and Shore (2005) used verbal protocols to collect data for investigating experts and novices' searching strategies on the Web. However, they also mentioned that the method of verbal protocol might interfere with participants' searching behaviors, and recommended that a natural environment or way for participants to display searching strategies and attributes was necessary. In contrast, in a series of studies about children's use of the Yahooligans! Web search engine, Bilal (2000, 2001, 2002) employed a screen-record software to acquire quantitative data for analyzing children's online searching behaviors. In a similar approach, this study followed Bilal's work to record participants' on-screen activities for further analysis, and proposed a new method for transcription, which highlights the mapping of connections among searching behaviors and their linkages to the completion of tasks.

The process of learners' searching behaviors may be various and should be highlighted by educators and researchers. Previous studies found that users utilized a variety of searching strategies when navigating on the Web (Drabenstott, 2003; Ford, Miller & Moss, 2003; Hölscher & Strube, 2000; Tsai, 2004b; Tsai & Tsai, 2003). For example, Tsai (2004b) proposed a framework of searching strategy, ranging from 'elaboration and exploration' to 'match', to display the information searching approaches used by learners on the Web. Web searchers, who employ an 'elaboration and exploration' approach, know clearly their searching purposes and express careful judgments of assessing Web information they have searched; on the contrary, learners will merely consider the best fit results as indicated by search engines if they utilize a 'Match' approach. It also showed that different online information searching strategies may lead to different learning outcomes (Tsai & Tsai, 2003).

Undoubtedly, 'information searching' is a complex cognitive task, which can promote students' effective learning, and must be carefully framed by educators (Rouet, 2003). Moreover, students' searching strategies and behaviors on the Web have been frequently investigated, since they are related to students' learning outcomes derived from Web-based environments (Hess, 1999; Hill, 1999; Tsai & Tsai, 2003).

2.3.3 Correlation between epistemological beliefs and online searching strategies

Students' epistemological beliefs may influence their learning behaviors and then lead them to employ various ways of learning. For example, Whitmire (2004) indicated that there was a relationship between epistemological beliefs and information-seeking behaviors. She found that undergraduate students with advanced development of epistemological beliefs showed greater ability to handle conflicting information resources and to recognize authoritative information sources, whereas students holding absolutist position merely selected information sources consistent with their own views. Similarly, it is plausible that students may develop various online searching strategies depending on diverse epistemological beliefs to handle the complexities of information on the Internet. This viewpoint was also evidenced by the results of Oliver and Hannafin's (2000) research which revealed that students with naïve epistemological beliefs tended to employ Web-related tools less effectively than those with advanced epistemological beliefs.

Consequently, students who developed and possessed advanced epistemological beliefs (e.g., constructivist-oriented beliefs) may evaluate, judge and think critically when navigating on the Web to find correct, useful, relevant and quality materials for Internet-based learning activities (Hofer, 2004). As she asserted the functionality of epistemological beliefs plays in the Internet-based learning activities:

> Fundamentally, as the way in which students access information has changed, we need to be aware of how individuals evaluate sources of knowledge, coordinate theory and evidence, and justify their knowledge assumptions, all aspects of epistemological thinking (p.51)

In the same way, it is possible that students may serve scientific epistemological views as the standards to judge science-related information when engaging in Internet-based learning activities regarding science. Additionally, students who display more advanced online searching strategies may clearly understand their purposes and select reliable information for some specific objectives. To that end, students' searching strategies may reflect their awareness of cognition, metacognition and epistemologies. Such perspectives had also been recommended by previous studies (Hofer, 2004; Tsai, 2004).

2.3.4 Conclusion

Recent studies have suggested that students' advanced searching strategies (i.e., cognitive and metacognitive strategies) may contribute to learning effectiveness and performance in Web-based learning environments (Oliver and Hannafin's, 2000; Rouet, 2003; Tsai and Tsai, 2003). Studies have also suggested that epistemological beliefs, what individuals believe about the nature of knowledge and knowing, are essential for students' processing of, and acquiring of, Web-based information (Hofer, 2001, 2004; Tsai, 2001, 2004a, 2004b). Epistemological beliefs, however, are even more critical in students' process of metacognitive activities (i.e., inquiry learning and reflective thinking), and judgment about the merits of the information on the Internet (Hofer, 2004; Schommer, 1997, Tsai, 2001, 2004a). In other words, students' information-searching strategies on the Internet may not only involve cognitive and metacognitive procedures but also incorporate with epistemological beliefs. Given these promises, Web-based learning activities may serve as cognitive, metacognitive, and epistemological tools simultaneously (Tsai, 2004a).

Hoffman *et al.* (2003) found that middle school students could construct meaningful understandings through online inquiry learning activities and suggested that students who employed appropriate search and access strategies might develop accurate and in-depth content understandings. It also had been supported that different online searching patterns may influence students' Internet-based learning performance (Calcaterra, Antonietti and Underwood, 2005). Hence, the use of sophisticated online searching strategies (e.g., metacognitive strategies) may be a key point of students' learning on the Internet to acquire relevant information and judge its correctness as well as usefulness (Tsai & Tsai, 2003).

The issues of online searching behaviors or information seeking behaviors have been broadly investigated and discussed in the field of information and library science (Bilal & Kirby, 2002; Drabenstott, 2003; Ford, Miller & Moss; Hsieh-Yee, 2001). However, there were fewer studies which mainly focused on investigating the role of online searching strategies and its relationship with personal epistemological beliefs (either domain-general or domain-specific) in educational research. As different epistemological beliefs may lead to different types of online searching strategies and the Internet may be employed as an epistemological tool to help students develop advanced beliefs through Web navigation (Tsai,2004a, 2004b), it is necessary to acquire a better understanding about the relation between epistemological beliefs and online searching strategies.

A hypothetical model shown in Fig 2.2 may illustrate the correlation between epistemological beliefs (e.g., ICs & SEVs), online searching strategies, and Internet-based learning.

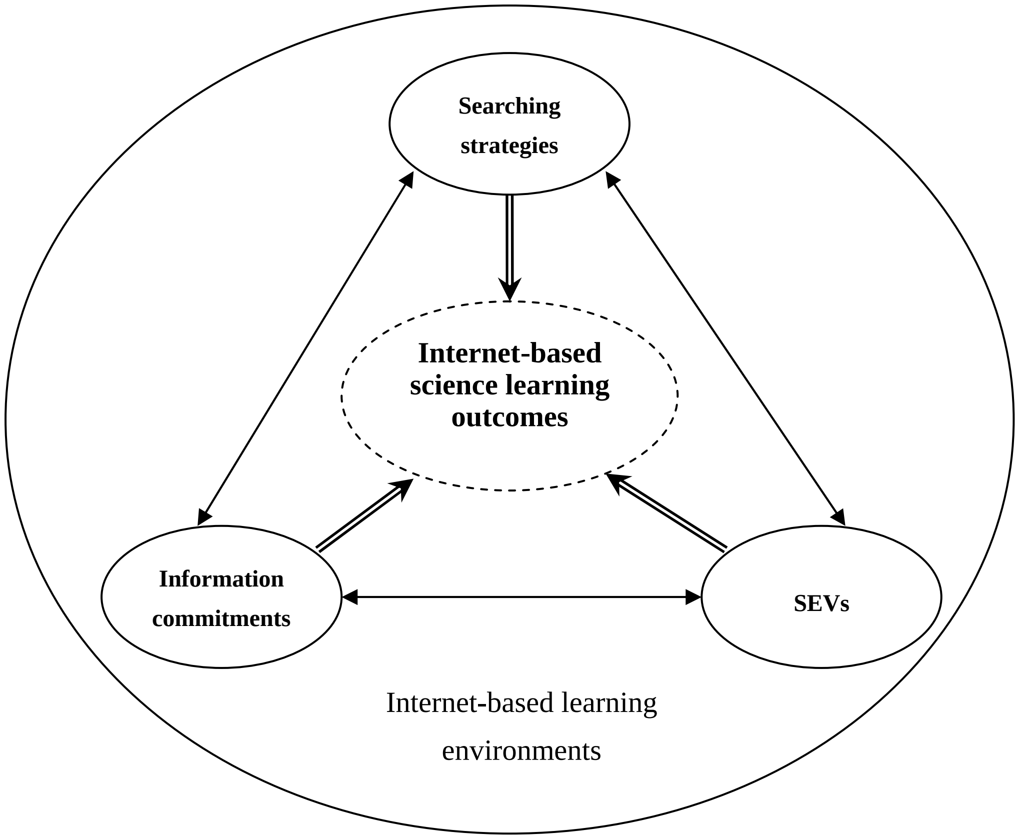


Fig 2.2. Three essential variables related to Internet-based science learning

By comparison with formal learning environment, students may base their epistemological beliefs as evaluative standards to filter online materials, develop and employ online searching strategies to find relevant resources and employ appropriate standards and strategies to accomplish Internet-based learning. Following the findings of Windschitl and Andre' s (1998) research which revealed that students with more advanced epistemological beliefs benefited more from open-ended and inquiry-oriented computer-assisted learning environments, this study further address the importance of advanced online searching strategies when navigating on the Internet. That is, both epistemological beliefs and online searching strategies may provide students with standards and skills to learn in the Internet-based environments.

Numerous studies found that students with advanced online searching strategies may perform better in the Internet-based learning environments. However, Schacter, Chung and Dorr (1998) have found that students did not really understand the information they look for, they merely complete the assignments by finding one best fit answer. Jonassen *et al.* (2003) asserted that searching for ‘right’ answer could not account for meaningful searching, and then resulted in learning. As a result, this study is intended to incorporate online searching strategies with the conceptions about epistemologies which serve as a series of evaluative standards to judge the correctness, usefulness and content of information on the Internet. Furthermore, except for the standards of judging Web information (e.g., information commitments), it is interesting to explore whether students’ scientific epistemological views salso contribute to their learning performance as searching online. Is there an interaction between students’ information commitments and scientific epistemological views? If so, possessing both domain-general and domain-specific epistemological beliefs (i.e., ICs and SEVs) may be important for students’ science learning in the Internet-based learning environments.

The main purpose in this study is to explore the interrelationships between students’ information commitments, scientific epistemological beliefs, and online searching strategies. Then, three variables are further compared with task performance to confirm the effectiveness of ICs, SEVs, and searching strategies in the Internet-based learning environments. By this way, it may make ‘meaningful online searching strategies’ possible, and then students can benefit greatly from Internet-based learning environments.

Chapter 3 – Methodology

3.1 Participants

This research is conducted with an initial group of 188 Taiwanese high school students (the 10^{th}-12^{th} grade, 47.9% male and 52.1% female), whose ages ranged from fifteen-year-old to eighteen-year-old, were chosen to complete both Information Commitments (ICs) survey and Scientific Epistemological Views (SEVs) questionnaire. Coming from varied regions and enrolling in some vocational programs, all the participants constitute a convenient sample. Students who enrolled in the course of Fundamental Natural Science[a] were selected from different classes in the same senior high school. A course related to the outlines of nuclear power in Taiwan has been introduced previously. In addition, these participants had a period of formal instruction to use computer and the Internet per week. In the course, they were asked to accomplish some assignments through the materials on the Internet. Also, over 90% of the participants had at least one computer, and 76% of these participants had access to the Internet at home. That is, all of participants were capable of searching relevant materials on the Web to fulfill purposes of specific subjects.

After confirming the reliability and validity of ICs and SEVs by initial group, 92 students were randomly selected to complete a science-related task on a work sheet by searching relevant resources on the Internet. However, for some losses of recorded files of screen-capture or work sheet, this study processed these as "missing" data. Therefore, 62 students were finally included for analysis and some important

[a] The purpose of Fundamental Natural Science course was to introduce junior high school students to basic conceptions about natural science in daily lives (e.g, different types of energy resources).

attributes are described in Table 3.1. Then, their on-screen activities were transformed into quantitative data using the Navigation Flow Map method (described later in next section) for analysis.

Table 3.1. Attributes of final samples (n=62)

Number of students	Mean age	The frequency of Internet usage (hours/per week)	Prior knowledge	Enrollment of vocational programs
20 (11/9)*	16.3	7.6	83	Layout design
17 (7/10)	17.1	11.3	77	Food and Beverage management
25 (8/17)	16.7	5.3	87	Business management

*(Male/Female)

Note:

Prior knowledge is mean score of achievement last semester

3.2 Instruments

There are two questionnaires employed in this study for assessing students' scientific epistemological views and information commitments. And a new method, Navigation Flow Map (NFM), was utilized to explore students' searching strategies quantitatively and qualitatively. Further, an in-depth interview was conducted to realize students' SEVs and ICs qualitatively.

3.2.1 Scientific epistemological beliefs

Scientific epistemological views (SEVs) questionnaire developed by Tsai and Liu (2005) involves nineteen items (presented as 6-point Likert scale) categorized into five dimensions for assessing students' epistemological beliefs toward science. More detailed explanations about these multiple dimensions are described as following:

1. The role of Social Negotiation: assessing students' beliefs about the science which relies on negotiations among scientists (constructivist-approach). An example in this dimension is as "New scientific knowledge acquires its credibility through the recognition by many scientists in the field."
2. Invented and Creative nature of science: measuring students' beliefs about the awareness of scientific reality being invented rather than discovered (constructivist-approach). A sample item in this dimension is as "Some accepted scientific knowledge comes from human's dreams and hunches."
3. The theory-Laden exploration: addressing the ideas scientists' personal research agendas may influence the scientific exploration (constructivist-approach). Example item is like "Scientists' research activities will be affected by their existing theories."
4. The Cultural impacts: addressing the culture-depended nature of the development of scientific knowledge. The sample item is like "Different cultural groups have different ways of gaining knowledge about nature."
5. The Changing and Tentative feature of science knowledge: measuring students' beliefs about the changing and tentative nature of scientific knowledge (constructivist-approach). Example item in this dimension is like "The development of scientific knowledge often involves the change of concepts."

Through analyzing responses of 613 high school students in Taiwan, the reliability (alpha) coefficients for these five scales respectively were 0.71, 0.60, 0.68, 0.71, and 0.60, as well as the entire instrument was 0.67. The results meet the satisfactory standard of internal consistency statistically.

3.2.2 Information commitments

The Information Commitments Survey, proposed by Wu and Tsai (2005), includes four scales about evaluative standards to judge the correctness and usefulness of information on the Web (i.e., multiple sources as correctness, authority as correctness, content as usefulness, technical issues as usefulness), and two scales about searching strategies to glean information on the Internet (i.e., elaboration and exploration as searching strategies, match as searching strategies). Twenty-four items for the six scales are presented in a six-point Likert scale (i.e., “strongly agree,” “agree,” “somewhat agree,” “somewhat disagree,” “disagree,” and “strongly disagree”). A detailed description about the part of evaluative standards in ICS as following:

1. “Multiple sources as correctness (MS scale)” is to measure whether students evaluate the correctness of Web-based information by referring to other Web sites, peers or printed texts. A sample item of this scale is: When I view on the Internet some information with which I am unfamiliar, I will try to find more Web sites to validate whether the information is correct.
2. “Authority as correctness (AU scale)” is to assess whether students examine the correctness of Web-based information by the reputation of the Web sites or sources. A sample item of this scale is: When I view on the Internet some information with which I am unfamiliar, I will believe in its accuracy if the information is posted on professional (official) Web sites.
3. “Content as usefulness (CO scale)” is to determine whether students judge the usefulness of Web-based information by the relevancy of its content. A sample item of this scale is: When I view or navigate information on the Internet, if it can help me search for relevant information, I will consider the information

useful to me.

4. "Technical as usefulness (TE scale)" is to assess whether students evaluate the usefulness of Web-based information by the ease of retrieving, searching and obtaining information. A sample item of this scale is: When I view or navigate information on the Internet, if it does not require a password or registration, I will consider the information useful to me.
5. "Elaboration and exploration as searching strategy (EL scale)" is to measure whether students have purposeful thinking or integrate Web-based information to fulfill their purposes. A sample item of this scale is: When I search for information on the Internet, I can use some acquired information for an advanced search to find the most-fit information.
6. "Match as searching strategy (MA scale)" is to investigate whether students use only a set of keywords to find a few Web sites that contain the most fruitful and relevant information. A sample item of this scale is: When I search for information on the Internet, I am eager to find a single Web site that contains the most fruitful information.

By surveying 1220 Taiwanese university students, the reliability (alpha) coefficients for each scale is 0.72, 0.82, 0.88, 0.76, 0.84, and 0.74, and the overall alpha is 0.80. These scores suggest that ICS has satisfactory reliability in the assessment of students' evaluative standards for judging the correctness and the usefulness of both Web information and searching strategies that target relevant information on the Internet.

Owing to the fact that the original ICS is being conducted with 1,220 undergraduate and graduate students in Taiwan, the present study has managed to modify the ICS and has re-examined its reliability and validity by analyzing a group of high school samples. On the college version of ICS, two scales (i.e., multiple sources as correctness and matching as searching strategy) have fewer items than other scales. This study further added six items to the revised ICS for equal items in each scale. Hence, the revised ICS for high school students including a total of thirty items was assembled by six scales. The added items are listed as follows:

When I view on the Internet some information with which I am unfamiliar,

1. I will refer to the response of network peers to judge whether the information is correct. (Multiple sources as correctness)
2. and if some information appears simultaneously on other relevant Web pages, then I will conclude that it is correct. (Multiple sources as correctness)
3. and if the Web information is provided by famous professionals, then I will believe in its correctness. (Authority as correctness)

When I view or navigate information on the Internet,

1. if the function of an advanced search is provided, I will consider the information useful to me. (Technical issues as usefulness)

When I search information on the Internet,

1. I usually use only a key word on a search engine to find relevant Web sites. (Match as searching strategy)
2. I usually adopt information from only one Web site to answer relevant questions. (Match as searching strategy)

Finally, a principle component factor analysis was employed to re-examine the reliability and the validity of revised ICs Survey for high school students.

3.2.3 Navigation flow map

In order to distinguish the differences of Web users' searching strategies and patterns, it is necessary to utilize some effective ways to reveal their seeking characteristics. Hence, we followed a similar approach as Bilal's (2000, 2001, 2002) works, but extended the methodology to include a novel method of graphically displaying and analyzing the connections among the search behaviors of the students and their consequent competencies in completing the assigned task.

A new method, called as 'Navigation Flow Map' method, was developed to analyze students' searching behaviors for depicting their searching strategies (Lin & Tsai, 2005). By applying screen capture software called 'Camtasia Recorder' to record students' on-screen activities for later analysis, including the way each participant searched information on the Web, the way he/she performed different tasks, and the way he/she answered the questions on the work sheets. The Screen recorded files provided sufficiently detailed information about the search behaviors needed to map them into NFM format. All recorded files were transcribed into the format of 'Web navigation flow map' to represent each participant's Web-searching strategies, procedures and behaviors, as shown in Figure 3.1.

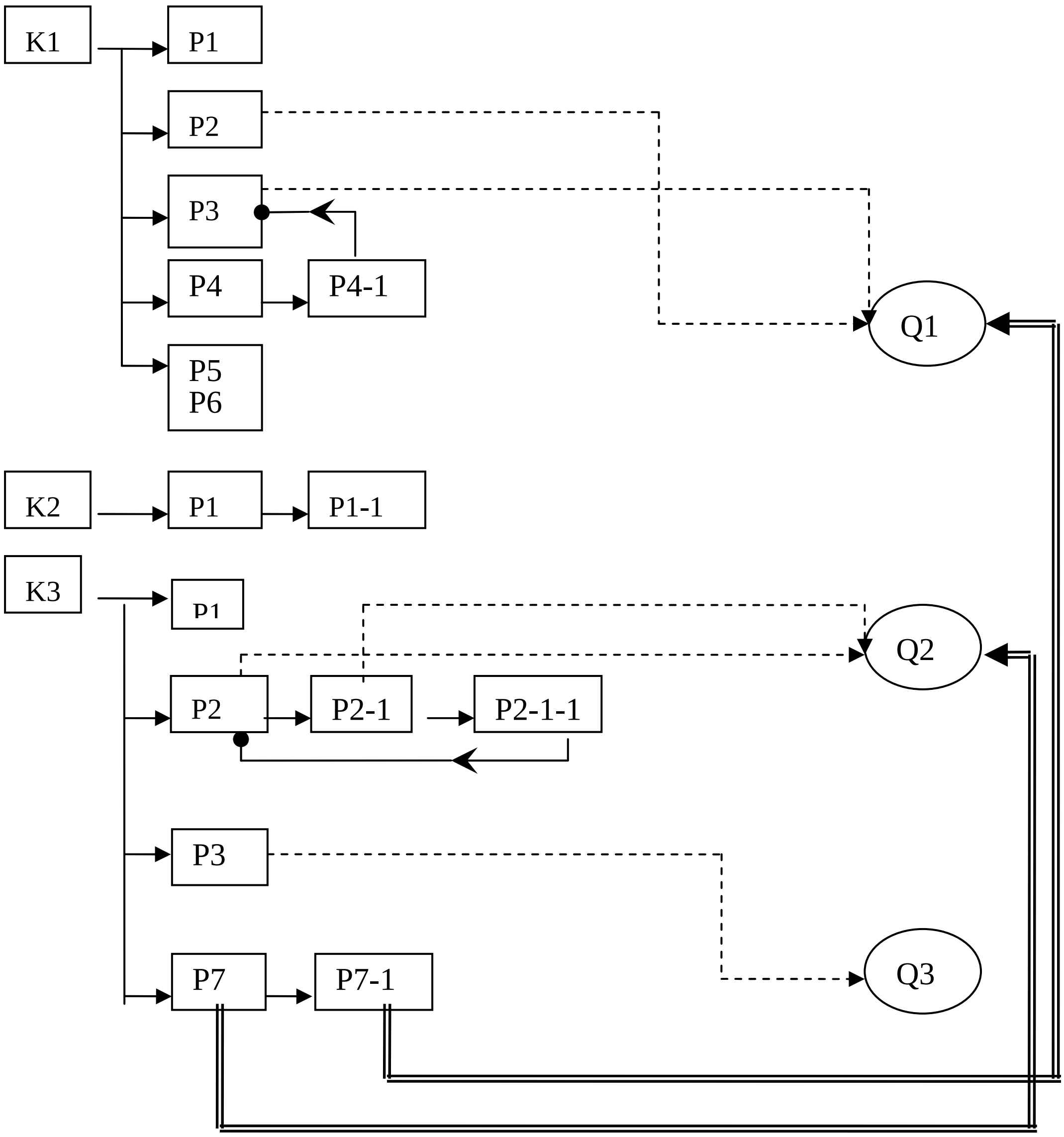


Figure 3.1 An example of navigation flow map

The symbol of 'K' in the navigation flow map indicated that the participant typed a keyword on a search engine to find some sources of relevant web pages. The web pages the participant selected to extract information for specific questions of tasks are represented by a mark of 'P'. In addition, the first number following the symbol indicates the sequential order of the used keywords and visiting pages, and a series of number following 'P' indicates the depth of visiting pages. For instance, P2-1-1 shows that the participant visited P1 and then navigated to its third level. The sign of 'Q1' represents the first question on the science or social task. In order to present the interrelation of Web actions, different types of line were employed. Lines with arrow showed the sequential processes and connections among keywords or web pages; a dotted line with arrow revealed that the participant selected information from pages to answer the questions of tasks. When the participants moved to previous visited pages, a line with spot are used to present linkage from one page to another. Dual (double) line with arrow showed that participants selected additional information from other pages to refine or to enrich their previous answer on the question. For example, as shown in Fig 3.1, participant utilized K1 for searching, and visited pages from P1 to P4-1. Then, she extracted information from two pages (P2, and P3) to respond to Q1 (first question in science task). Moreover, participant revisited P3 (from P4-1) and extracted information to Q1 again.

In addition, the navigation flow map showed another action of refinement or replacement between seeking behavior and task. While dotted line shows the participant's addition of information to answer questions, the dual line involves a revision or refinement original information to improve the quality of answers. In the refinement process, the participant tried to modify and enrich the answer, not just to add information. For instance, Fig 3.1 showed that participant selected P7 and P7-1 of the third keyword to refine Q1 and Q2. A complete structure of navigation flow map clearly showed all of the actions and their sequences on the Web for the task, and all of the participants' navigation flow maps can be developed by similar rules

Furthermore, to refine and amplify the analyses that are possible with NFMs, six quantitative indicators were proposed as follows:

Number of keywords: the amount of keywords the participant used to search relevant information to perform task, shown as 'K-number' on the navigation flow map; e.g., there are three keywords (K1 to K3) in Fig 3.1. This indicator shows the variations of the keywords for searching information.

Revisited pages: the number of Web pages in which the participant revisited, shown as the total number of lines with spots on the navigation flow map; e.g., there were two revisiting actions (two lines with spots) in Fig 3.1. This indicator represents the degree of recursion for searching navigation.

Maximum depth of exploration: the maximum level of the Webpages that the participant explored when searching information to answer the task questions; e.g., P2-1-1 (three layers) was the maximum level of Webpage in Fig 3.1. The indicator shows the depth of exploration.

Webpage adoptions: number of retrieving information from some pages for performing a certain task (presented as dotted lines in NFMs); e.g., participant selected five Webpages (P2, P3 from K1, P5, P5-1 and P6 from K3) to complete the task, as shown in Fig 3.1. This indicator represents the variation of adopting information sources for the task.

Total depth of Webpage adoptions: For example, Fig 3.1 showed that participant selected P2, P3 (one layer of depth) from K1, P5, P5-1 (two layers) and P6 from K3 to perform the questions, so her total depth of Webpage adoptions per question is 6 (1×4+2). This indicator shows the total depth of Webpage adoptions for completing the task.

Additional Webpages for refinement: the number of Web pages in which the participant chose to refine tasks, shown as the number of dual lines with arrows on the navigation flow map. e.g., participant selected two pages (P7 and P7-1 from K3) to refine original answers of Q1 and Q2 respectively, as shown in Fig 3.1. Therefore, her value on this indicator is 2. This indicator shows the participant's frequency of refining or improving the quality of task answers, which is related to their metacognitive ability for reflecting and monitoring searching process on the Web.

3.2.3.1 A pilot study of college samples

Six volunteers (three women and three men) attending graduate schools in Taiwan were selected for in-depth case studies. Coming from various regions and having varied majors, all the participants constitute a convenience sample. Their majors were in two different areas: natural science (e.g., chemistry, mathematics) and social studies (e.g., language). All of them had more than five years of experience using the Web and sufficient ability to deal with computer-based Word processing to accomplish the goals of the learning task. In addition, all of them had previously searched relevant materials on the Internet to complete specific assignments in college work. Hence, they were expected to have acquired basic computer abilities and be capable of effectively participating in research that required a variety of web-based searches.

There were two searching tasks implemented: one was related to a nuclear energy plant in Taiwan (scientific task); the other was related to the aboriginal people in Taiwan (social task). These two topics were introduced previously to high school students in a formal curriculum in Taiwan, and it could be assumed that all the participants were capable of utilizing the Internet to find relevant information for answering the task questions. Each task included a work sheet with three questions as follows:

Scientific-related task:

1. What are the scientific principles related to nuclear energy?
2. Please list the advantages and disadvantages of using nuclear energy.
3. What was the utility rate of nuclear power in Taiwan?

Social-related task:

1. How many recognized aboriginal clans are there in Taiwan? (Please list ten clans at least)
2. Please list their distribution in Taiwan. (north, middle, south, east and outside the island)
3. What was the percentage of aboriginal population for each clan in Taiwan?

In order to evaluate the participants' performance on the searching tasks, two trained researchers initially consulted with each other to establish three evaluative criteria for grading, i.e. 'Accuracy,' 'Richness,' and 'Integration'. The criterion of 'Accuracy' pertains to evidence of correctness and suitability of the answers. The criterion of 'Richness' is used to assess the extent and abundance of materials that the participants select from Webpages to answer the questions. Finally, the criterion of 'Integration' is used to examine the students' degree of evaluating, comparing and integrating materials during completion of the assigned task. Each criterion was given a score with a range from 1 to 10. Two researchers scored the students' performance independently. Using a Spearman's pair-wise correlation method, the inter-rater reliability was .81 for the scientific task and .79 for the social task, which was statistically significant for both measures. Hence, we conclude that the researchers achieved an acceptable internal consistency while scoring the participants' performance on the two tasks. The method of Spearman's correlation analyses has been generally employed to report internal consistency based on the scores of researcher pairs (Johnson, Penny & Gordon, 2000).

The six participants were individually scheduled to perform two different tasks (including three questions for each task) by utilizing open-ended Internet resources. The participants could freely select any searching engine to find relevant materials, and then filter appropriate information to complete the tasks. Moreover, to acquire a better understanding of participants' searching processes, no constraint was placed on the time needed by the participant. Participants could not sign off from a task, however, until they had completed two different searching tasks. The whole process had to be finished directly on the computer, and all on-screen activities were recorded by the screen-capture software. These files were analyzed by the first author and further validated by another researcher who was fully trained in the NFM methodology.

3.2.3.2 Qualitative features of Navigation flow maps

By reviewing and comparing the participants' navigation flow maps, we found some interesting individual differences among the participants' search behaviors. Comparing Figures 1 and 3 shown in appendix A (participants B's and E's navigation flow maps for the same scientific task), it is clear that Figure 3 displays more complicated searching structures, abundant trials, frequent looping and refinements than the data in Figure 1. Some participants (i.e., A, B and C) merely selected a single source to answer questions, whereas others (i.e., D, E and F) tended to retrieve information from different pages. Moreover, participants E and F more frequently revisited previous pages as shown by a greater number of recurrent linking lines with arrows. We also found that some participants (i.e., D, E and F) selected other pages to refine finished tasks, whereas others did not modify answers after finishing the tasks. For instance, comparing participant B's and E's navigation flow maps in the social task (Figures 2 and 4 shown in appendix A), participant E had more Webpage adoptions, actions of revisiting pages, and additional pages for refinement when answering each question than participant B who merely found a few pages to glean information to answer the questions.

By reviewing critical features and tendencies of the participants' behaviors as shown in NFMs, two trained researchers individually categorized six participants into two different groups: one was categorized as an 'Exploration' group including participants D, E and F; and another as a 'Match' group involving participants A, B and C. By contrast to the participants categorized in the 'Match' group, we found that those in the 'Exploration' group usually used richer keywords to find relevant pages, browsed and revisited more pages deeply, selected multiple sources to complete tasks, and refined previous answers with more conscious reflection. These findings correspond well to Tsai's (2004b) observations comparing expert and novice Web searcher. The online exploring traits of experts were very similar to the 'Exploration' group in the current study, and the experts usually performed more skillfully than novice students whose search behaviors were more like those of the 'Match' group. However, to more carefully characterize and compare search strategies between the 'Exploration' group and 'Match' group, the six quantitative indicators about search patterns described previously were employed. .

3.2.3.3 Quantitative indicators derived from Navigation flow maps

Quantitative descriptive data, based on an analysis of the NFMs of six participants, are presented in Table 3.2. In general, the data showed that participants in the 'Exploration' group had higher scores on the six quantitative indicators than those in the 'Match' group. Based on the average indicator scores, the participants in the 'Exploration' group, compared to those in the 'Match' group, used more keywords (8.17 versus 2.17), accessed more Webpages (7.33 versus 2.83), and navigated Webpages more deeply (3.83 versus 2.33 for 'Maximum depth of exploration', and 13.83 versus 5.5 for 'Total depth of Webpage adoptions'). That is, the participants in the 'Exploration' group (students D, E and F) tended to renew keywords more frequently, and revisit previous pages and adopt different pages more extensively than those in the 'Match group' (students A, B, and C).

The score of 'Maximum depth of exploration' showed that all participants browsed Webpages to different levels; however, the participants in the 'Exploration' group generally accessed Webpages with greater depth and breadth as part of their searching strategies. More importantly, there were evident differences between the 'Exploration' and the 'Match' groups on two rather significant quantitative indicators: 'Revisited Webpages' and 'Additional Webpages for refinement'. The 'Exploration' group average scores on the two indicators were respectively 5.17 and 1.17, but no instances were observed for the 'Match' group (Table 3.2). Although there were differences on all six indicators between the 'Match' and 'Exploration' groups, the differences in the frequencies of the indicators 'Revisited Webpages' and 'Additional Webpages for refinement' provided the most clear-cut evidence of the differences in the sophistication of the search strategies for the two groups.

Table 3.2. Quantitative indicators derived from navigation flow maps

				Number of keywords	Maximum depth of exploration	Webpage adoptions	Total depth of Webpage adoptions	Revisited Webpages	Additional Webpages for refinement
Group	*Gender*	*Participant*	*Task*						
Match	Female	A	Scientific	2	1	3	3	—	—
			Social	2	1	3	3	—	—
	Male	B	Scientific	4	3	3	6	—	—
			Social	2	3	3	6	—	—
	Male	C	Scientific	2	3	3	6	—	—
			Social	1	3	2	9	—	—
Average				2.17	2.33	2.83	5.5	—	—
Exploration	Female	D	Scientific	3	4	2	4	—	2
			Social	8	2	5	7	1	—
	Female	E	Scientific	4	5	13	37	11	—
			Social	3	3	4	6	4	2
	Male	F	Scientific	13	4	5	7	10	2
			Social	18	5	15	22	5	1
Average				8.17	3.83	7.33	13.83	5.17	1.17

Table 3.3. Between-task comparisons using six quantitative indicators

Task	Group	Number of keywords	Maximum depth of exploration	Webpage adoptions	Total depth of Webpage adoptions	Revisited Webpages	Additional Webpages for refinement
Scientific	Match	8	7	9	15	—	—
	Exploration	20	13	20	48	21	4
	Sub-total	28	20	29	63	21	4
Social	Match	5	7	8	18	—	—
	Exploration	29	10	24	35	10	3
	Sub-total	34	17	32	53	10	3

Interestingly in contrast, between-task comparisons (scientific versus social task groups) showed no apparent differences in the ‘Number of keywords’ and ‘Webpage adoptions’ (Table 3.3). However, the data on ‘Revisited Webpages’ reveals that the participants (those with ‘Exploration’ group) in the science-based task consistently tended to review additional pages to confirm the correctness and effectiveness of the information accessed, rather than using only one page, as was the case with participants who accessed information on social issues. This study compared students’ searching strategies across different tasks. Future research studies that examine the relationships between the kinds of questions posed in the tasks and the search strategies of the participants, as analyzed by NFMs, would be of interest.

Generally, in this study there is evidence that students who were engaged in different tasks used different search strategies. It is obvious that the participants in the ‘Exploration’ group were more skillful and sophisticated than those in the ‘Match’ group. For example, they usually changed keyword formats when using the search engine to yield finer results, revisited information presented in different pages and selected different pages as an information base to answer questions. That is, with respect to their approach in selecting information, participants in the ‘Exploration’ group attempted to compare, filter and integrate information when searching on the Internet; by contrast, members in the ‘Match’ group showed more simplistic searching strategies when seeking materials for a specific task.

3.2.3.4 Participants’ performance on the tasks categorized by different groups

As described in Section 3.2.3.1, two trained researchers scored the task performance from 1 to 10 for three aspects: ‘Accuracy’, ‘Richness’, and ‘Integration’ respectively, and average scores were obtained for the ‘Exploration’ and ‘Match’ groups, subdivided by task (Table 3.4). The ‘Exploration’ group consistently attained higher scores than those in the ‘Match’ group (scientific and social task subgroups) for all three aspects. Moreover, overall, the ‘Exploration’ group had much better performance (total 149.5) than the ‘Match’ group (total 118.5) as shown in Table 3.4.

The data in Table 3.4 imply that students in the ‘Exploration’ group seem to have a better awareness of evaluating the correctness of Web-based information, and overall they collected more reliable resources to complete the task. Consequently, students with advanced searching strategies may be more proficient in Internet-based learning environments as noted in previous publications (Oliver & Hannafin, 2000; Rouet, 2003; Tsai & Tsai, 2003).

Table 3.4. Participants’ performance on the tasks, sorted by task content (rows) and strategies (columns)

Group	Exploration (Participants D, E and F)	Match (Participants A, B and C)
Scientific task	*Score*	*Score*
Accuracy	25 (8 / 10 / 7)*	20.5 (5.5 / 7 / 8)
Richness	25 (7.5 / 10 / 7.5)	19.5 (5 / 6.5 / 8)
Integration	26 (8.5 / 10 / 7.5)	18.5 (5 / 6 / 7.5)
sub-total	76 (24 / 30 / 22)	58.5 (15.5 / 19.5 / 23.5)
Social task	*Score*	*Score*
Accuracy	24.5 (9 / 8 / 7.5)	21 (7 / 7.5 / 6.5)
Richness	24 (8 / 7.5 / 8.5)	20.5 (7 / 7 / 6.5)
Integration	25 (9 / 8 / 8)	18.5 (6 / 6.5 / 6)
sub-total	73.5 (26 / 23.5 / 24)	60 (20 / 21 / 19)
Total	149.5	118.5

*(8 / 10 / 7) indicates the score by participants D, E and F respectively was 8, 10 and 7

3.2.4 Science-related searching task

In order to capture and depict students' searching strategies, the participants will be asked to complete pre-designed learning activities by seeking relevant information and resources on the Internet. This study revised a science-related searching task employed by previous studies (Lin & Tsai, 2005; Tsai & Tsai, 2003). Students have to complete a work sheet by searching relevant information on the Internet. The topic of science-related task is related to "What principles that scientists stand to change nuclear power into the electric power?"

The participants can freely select any searching engine to find relevant materials, and then filter appropriate information to complete the assignment. The whole procedure is limited in 20 minutes, and all on-screen movements are recorded by screen-captured software and transcribed into navigation flow maps. To evaluate the participants' learning performance on the searching assignment, two trained researchers initially consulted with each other to establish some main concepts and relations about nuclear power for grading, as shown in Table 3.5.

Table 3.5. Concepts and relations about nuclear power for evaluating students' task performance

Main concepts	1. uranium (U-235) 2. nuclear fission 3. chain reaction 4. thermal energy 5. mechanical energy
Main relations	1.U-235 produces huge heat via nuclear fission and a chain reaction 2.Heat energy produces the high-pressure and temperature vapor to promote the turbine 3. The turbine drives the generator to cut the magnetic field, change the mechanical energy into producing the electric energy

Two researchers scored the students' performance independently. Students' task performance was given a score with a range from 0 to 8 according to the appearances of main concepts and relations involved on the work sheet. Each student was scored twice, and average score was employed to represent students' performance. Using a Spearman's pair-wise correlation method, the inter-rater reliability was .77 for the scientific task which was statistically significant for both measures. The method of Spearman's correlation analyses has been generally employed to report internal consistency based on the scores of researcher pairs (Johnson, Penny & Gordon, 2000). Hence, we concluded that the researchers achieved an acceptable internal consistency while scoring the participants' performance on the two tasks.

3.2.5 Students' interviews

In order to acquire a better understanding about the relationships between students' scientific epistemological views and information commitments, this study conducted some interview questions which mainly followed works of Tsai and Liu (2005) and Tsai (2004b) to two groups categorized by students' sum scores of all SEVs subscales. One was "constructivist-oriented" group categorized by top 10% scores of the SEVs instrument; the other one was "empiricist-aligned" group categorized by bottom 10% scores of the instrument. In each group, two male and two female students were randomly selected to answer questions about SEVs and ICs. Audio records were transcribed by two trained researchers. Because the interviews were conducted in Chinese-language, all of the data presented in this study had to be transcribed after the authors' translation and was further examined by an independent listener. The qualitative findings were used not only to validate the quantitative results, but also to provide some plausible interpretations for the conclusions made within this study.

3.3 Procedure of data collection

The sixty-two students in final group were individually scheduled to perform science-related task by utilizing open-ended Internet resources. The participants could freely select any searching engine to find relevant materials, and then filter appropriate information to complete the task. However, in this study for high school students' searching strategies, students must finish the task under the restrictions of 20 minutes. Participants could not sign off from a task, however, until they had completed it. The whole process had to be finished directly on the computer, and all on-screen activities were recorded by the screen-capture software. These files were analyzed by the author and further validated by another researcher who was fully trained in the NFM methodology.

Chapter 4 - Results

4.1 Reliability of SEVs

Through analyzing responses of 188 high school students on SEVs, Table 4.1 shows that the reliability (alpha) of the five dimensions in the SEVs questionnaire ranged from .60 to .7, and its overall alpha (0.79), indicating an acceptable level for its internal consistency. Table 4.1 also revealed that students scored highest on the social negotiation scale (an average of 5.00 per item), followed by the invented and creative scale (an average of 4.94 per item), the culture impact scale (an average of 4.72 per item), the changing and tentative scale (an average of 4.67 per item), the theory-laden scale (an average of 4.32 per item).

The reliability coefficient of "The cultural impacts" is lowest among the dimensions, but a low Cronbach's alpha coefficient as .55 can be accepted for social science studies (Hatcher & Stepanski, 1994). The result revealed that students' score on SEVs questionnaire was reliable to represent their epistemological beliefs toward science and could be employed for examining its relationships with other factors proposed in the present study.

Table 4.1. Means, Standard Deviations, Range, and Cronbach's Alpha Reliabilities for SEVs (n=188)

	N	Range	Mean	SD	Cronbrach's α
SEVs					
IC	4	2.75-6.00	4.94	0.77	0.65
TL	3	2.00-6.00	4.32	0.76	0.61
CT	3	1.33-6.00	4.67	0.69	0.65
SN	6	3.00-6.00	5.00	0.66	0.75
CU	3	2.00-6.00	4.72	0.71	0.59
Overall α= 0.79					

Notes:

IC: The invented and creative nature of science

TL: The theory-laden exploration

CT: The changing and tentative features of scientific knowledge

SN: The role of social negotiations

CU: The cultural impacts

4.2 Factor analysis of revised ICs for high school students

Unlike the questionnaire for assessing SEVs, which was mainly designed for high school students, ICs survey was conducted with 1,220 undergraduate and graduate students in Taiwan. Thus, there was a need to re-examine reliability and validity of revised ICs survey by analyzing a group of high school student samples. In this study, we employed a principle component factor analysis to analyze 31 items of the revised ICs survey. Items with a factor loading value less than .50 are subject to deletion. Analysis revealed six scales with eigenvalues that are greater than 1 (5.51, 3.48, 2.33, 1.99, 1.63, and 1.39, as shown in Table 1) and they accounted for 56.3% of the total variance. The initial 31 items of the revised ICs were reduced to 29 items that are quite equally distributed to six scales. Table 4.2 shows both the factor loadings for the retained items and the reliability for each scale.

Table 4.2. Rotated factor loadings and Cronbach's values for the six factors (scales) of Information Commitment Survey (n=188)

Item	Factor 1:	Factor 2:	Factor 3:	Factor 4:	Factor 5:	Factor 6:
Factor 1: *Multiple sources* =0.75						
Multi. sour. 1	0.701					
Multi. sour. 2	0.795					
Multi. sour. 3	0.613					
Multi. sour. 4*	0.722					
Factor 2: *Authority* =0.77						
Authority 1		0.720				
Authority 2		0.703				
Authority 3		0.638				
Authority 4		0.788				
Authority 5*		0.628				
Factor 3: *Content* =0.80						
Content 1			0.708			
Content 2			0.727			
Content 3			0.753			
Content 4			0.661			
Content 5			0.626			
Factor 4: *Technical* =0.71						
Technical 1				0.669		
Technical 2				0.594		
Technical 3				0.713		
Technical 4				0.732		
Technical 5*				0.642		
Factor 5: *Elaboration and exploration* =0.79						
Elaboration 1					0.744	
Elaboration 2					0.813	
Elaboration 3					0.540	
Elaboration 4					0.635	
Elaboration 5					0.611	
Factor 6: *Match* =0.81						
Match 1						0.589
Match 2						0.756
Match 3						0.824
Match 4*						0.772
Match 5*						0.769
Eigen-value	5.51	3.48	2.33	1.99	1.63	1.39
% of variance	19.00	12.01	8.02	6.85	5.63	4.79

Overall =0.82, total variance explained is 56.3%

NOTE: item-number* means the added item on the revised ICs survey

The results indicated that the constructs of the revised ICs survey are parallel to those of the college-version and that they can therefore be considered an appropriate degree of validity. The reliability (Cronbach's α) for each scale is .75, .77, .80, .71, .79, and .81, with an overall alpha value of .82. Thus, the revised version of ICs survey is capable of measuring information commitments for high school students in Taiwan.

Table 4.3 shows students' average item scores and standard deviations on the six scales of the ICs survey. According to Table 4.3, students scored highest on the content scale (an average of 5.21 per item), followed by the elaboration scale (an average of 4.90 per item), the multiple sources scale (an average of 4.71 per item), the authority scale (an average of 4.23 per item), the match scale (an average of 3.96 per item), and the technical scale (an average of 3.55 per item).

Table 4.3. Means, Standard Deviations, Range, and Cronbach's Alpha Reliabilities for ICs (n=188)

Ics	n	Range	Mean	SD
Multiple sources	4	1.75-6.00	4.71	0.86
Authority	5	2.00-6.00	4.23	0.85
Content	5	3.00-6.00	5.21	0.66
Technical	5	1.20-5.60	3.55	0.79
Elaboration	5	2.20-6.00	4.90	0.76
Match	5	1.40-6.00	3.96	1.08

As shown in Table 4.4, there are several significant correlations between the scales of the senior high school version of the ICs. These relationships revealed that "Elaboration and exploration as searching strategies" was significantly correlated to both "Multiple sources as correctness" ($r=.46, p<.01$) and "Content as usefulness" ($r=.51, p<.01$); whereas "Match as searching strategies" is significantly correlated to both "Authority as correctness"' ($r=.23, p<.01$), and "Technical as usefulness" (r=.16, p<.05). In addition, the scale of "Authority as correctness" is positively correlated to both scales of "Content as usefulness" and "Technical as usefulness". The results of correlations among scales also correspond to previous research conducted by Wu and Tsai (2005) that intertwining relationships existed among six components of ICs. For example, students having "multiple sources" and "content" as evaluative standards may exhibit "exploration" searching strategies, whereas others with "authority" and "technical" standards may employ "match" searching strategies. In sum, the results of our factor analysis on the revised ICs survey can be applied to assess the information commitments of high school students in Web-based learning environments.

Table 4.4. Inter-correlation matrix of the six factors of the revised ICs (n=188)

Information Commitments factors	Multiple sources	Authority	Content	Technical	Elaboration	Match
Multiple sources	--					
Authority	.13	--				
Content	.35**	.29**	--			
Technical	.05	.24**	.12	--		
Elaboration	.46**	.11	.51**	.04	--	
Match	.072	.23**	.11	.16*	.01	--

* p < .05, **p<.01

4.3 students' searching strategies and gender difference

Table 4.5 presents students' features of searching strategies extracted from their searching behaviors. By observing and analyzing 62 high school students' on-screen searching behaviors (twenty-six male and thirty-six female) and comparing with previous result of pilot study, we found that high school students rarely navigated

Webpage with deeper layer or selected additional Webpages for refining previous answer to accomplish searching task in this study. For example, by comparing to pilot study for college samples (Table 4.5 and Table 3.4), high school students might use less keyword (average 2.53 v.s. 5.17), navigated more shallow depth of site (average 8.18 v.s. 9.67), adopted fewer pages for performing the task (1.23 v.s. 5.08) and never refined previous work. In addition, due to the time constraint, students might manage time differently to deal with encountering information on the Internet. For instance, high school students may have different time management on browsing results from search engine, scanning sites they chosen and webpages they selected for answers. Thus, for a careful examination of high school students' searching strategies, we further added three indicators (i.e., Time of browsing result, scanning Webpage and Webpage adoption) and eliminate two indicators (i.e., Maximum depth of exploration and Additional Webpages for refinement) for analyzing Taiwanese high school students' searching behaviors. Time of browsing result is the total time that students spent on filtering the results directly generated from particular search engine (i.e., Yahoo) by entering specific keywords. Time of scanning Webpage presents the total time that students spent on finding information on some Webpages chosen from the search results, and time of Webpage adoption shows the total time that students spent on the Webpges they eventually selected for answering the task. For example, students in this study spent average 109.98 seconds on browsing results from search engine. When selecting particular pages, they spent average 190.61 seconds on scanning selected pages to find proper information. Finally, they spent average 81.73 seconds on the adopted pages they chose for performing science-related task, as shown in Table 4.5. These three indicators about time allocation may indicate students' retention period in studying Webpages. Table 4.5 presents nine indicators extracted from sixty-two high school students' searching behaviors.

Table 4.5. Students' searching strategies extracted from searching behaviors (n=62)

	Range	Mean	S.D.
Number of keywords	1-7	2.53	1.72
Time of browsing result (sec)	3-460	109.98	110.52
Time of scanning Webpage (sec)	24-622	190.61	132.77
Number of Webpage	1-20	6.11	4.15
Total depth of Webpage	1-39	8.18	7.24
Revisited Webpage	0-4	0.71	1.03
Webpage adoption	1-3	1.23	0.49
Total depth of Webpage adoption	1-6	1.58	1.03
Time of Webpage adoption (sec)	5-282	81.73	72.28

To explore whether there were gender differences between male and female students' searching strategies, this study analyzed the searching strategies of two genders (twenty-six male and thirty-six female). Table 4.6 presents that male and female students' searching strategies showed a statistical difference on total depth of Webpage adoption (1.27 versus 1.81, $p<.05$). No other significant differences between genders were found in the other indicators of searching strategies proposed in this study. But the results showed that female students selected more Webpages with deeper layer to accomplish the science-related task than did male ones. Tsai and Lin (2004), investigating Internet attitudes and self-efficacy between genders, found the surprising results that female students showed better self-efficacy than did male ones. And students' Internet self-efficacy may be related to what strategies they use for searching information (Tsai & Tsai, 2003). It may explain why female students navigated deeper pages and chosen it as answer resources than male students did in the present study.

Table 4.6. Gender comparisons on the searching strategies (n=62)

	Gender	N	Mean	S.D.	t-value
Number of keywords	Male	26	2.81	1.88	1.07(n.s.)
	Female	36	2.33	1.60	
Time of browsing result (sec)	Male	26	93.88	89.65	-0.97(n.s.)
	Female	36	121.61	123.35	
Time of scanning Webpage (sec)	Male	26	191.46	158.63	0.04(n.s.)
	Female	36	190.00	112.92	
Number of Webpage	Male	26	5.92	4.41	-0.30(n.s.)
	Female	36	6.25	4.00	
Total depth of Webpage	Male	26	7.35	6.81	-0.77(n.s.)
	Female	36	8.78	7.58	
Revisited Webpage	Male	26	0.62	1.06	-0.61(n.s.)
	Female	36	0.78	1.02	
Webpage adoption	Male	26	1.12	0.33	-1.65(n.s.)
	Female	36	1.31	0.58	
Total depth of Webpage adoption	Male	26	1.27	0.45	**-2.35***
	Female	36	1.81	1.26	
Time of Webpage adoption (sec)	Male	26	75.77	60.07	-0.55(n.s.)
	Female	36	86.03	80.52	

*p<0.05

n.s.: not significant

4.4 Relations between students' searching strategies, ICs, SEVs and science-related task performance

4.4.1 Searching strategies and task performance

Firstly, the correlation analysis was used to reveal interrelations among students' searching strategies, information commitments, scientific epistemological views and science-related task performance in this study. As shown in Table 4.7, there are no significant relationships between students' Internet usage experience (i.e., hours per week) and searching strategies. This finding may conflict with assertion that students' internet experience may affect how they seek information on the Internet in literature review (Hsieh-Yee, 2001). However, the finding of Lazonder (2000) found that the difference between experts' and novices' searching strategies may decrease as the searching task became more complex. Owing to the complexity of science-related task in this study that students must indicate the main concepts (e.g., chain reaction) and explain how nuclear power was transformed into electric power, it might somewhat explain the inconsistent results that students' Internet experience was not related to their searching strategies in the present study.

Table 4.7. Correlations between searching strategies, Internet experience, information retrieval and task performance (n=62)

	Internet usage experience	Amount of information	Task performance
Number of keyword	0.09	-0.12	-0.05
Time of browsing result (sec)	0.01	-0.22	-0.04
Time of scanning Webpage (sec)	-0.19	0.19	**0.40*** **
Number of Webpage	-0.17	0.03	0.08
Total depth of Webpage	-0.22	0.14	0.19
Revisited Webpage	-0.04	0.15	0.16
Webpage adoption	-0.18	**0.35** **	0.14
Total depth of Webpage adoption	-0.14	**0.28***	0.1
Time of Webpage adoption (sec)	-0.14	**0.32***	**0.38** **

$^*p<.05$, $^{**}p < .01$, $^{***}p<.001$

The amount of information is a variable to compute the quantity of information that the students selected for completing task. It found that Webpage adoption ($r=0.35$, $p< .01$), total depth of Webpage adoption ($r=0.28$, $p< .05$) and time of Webpage adoption ($r=0.32$, $p< .05$) were positively correlated to the amount of information. That is, students who selected information from different Webpages with deeper level may collect abundant materials to enrich their task. In addition, time of scanning Webpage ($r=0.4$, $p< .001$) and time of Webpage adoption ($r=0.38$, $p< .01$) were significantly correlated to students' task performance. Positive relationships between searching strategies and task performance revealed that students who spent more time examining information presented on Webpages might acquire proper and reliable materials to accomplish science-related task. Thus, within limited time for Internet searching, it can be supposed that how students allocated time on some critical searching strategies, such as scanning Webpage and inspecting Webpage adoption, may influence the quality of task performance.

4.4.2 Students' information commitments and searching strategies

Table 4.8 presents interrelationships between students' information commitments, searching strategies, information retrieval and task performance. Two scales of ICs (i.e., multiple sources as correctness and content as usefulness) were significantly correlated to two indicators of searching strategies (i.e., time of scanning Webpage and time of Webpage adoption). It shows that students who believed multiple sources and content as important standards for collecting and validating Web-based information might spend more time browsing Webpage they selected and adopted for performing task. Also, multiple sources as correctness ($r=0.60$, $p<.001$) and content as usefulness ($r=0.49$, $p<.001$) were positively and significantly related to task performance. The results corresponded to the assertion that students' information commitments may affect their Web-learning behaviors (e.g., searching strategies) and learning outcomes (Tsai, 2004b). Moreover, significant correlation between multiple sources and the amount of information ($r=0.45$, $p<0.001$) revealed that students who recognized multiple sources as a standard to collect proper materials may retrieve more information to perform science-related task. Thus, these two standards for assembling and evaluating Web-based information resources may be crucial for students' Internet-based learning.

Table 4.8. Inter-correlation between ICs, strategies of searching strategy, amount of information retrieval and Task performance and (n=62)

	Multiple sources as correctness	Authority as correctness	Content as usefulness	Technical as usefulness	Elaboration as searching strategy	Match as searching strategy
Number of keyword	-0.04	0.14	-0.12	-0.17	-0.08	-0.11
Time of browsing result (sec)	-0.07	0.00	-0.06	-0.17	0.04	-0.10
Time of scanning Webpage (sec)	**0.40*** **	0.12	**0.37** **	-0.05	0.24	0.04
Number of Webpage	0.13	0.24	0.06	-0.03	0.03	-0.01
Total depth of Webpage	0.14	0.15	0.15	0.04	0.05	0.03
Revisited Webpage	0.18	0.04	0.10	-0.04	-0.07	-0.01
Webpage adoption	-0.13	0.08	0.06	0.17	-0.01	-0.01
Total depth of Webpage adoption	0.00	0.03	0.09	0.17	-0.06	0.01
Time of Webpage adoption (sec)	**0.38** **	-0.04	**0.47*** **	0.01	0.21	-0.04
Amount of information	**0.45*** **	0.22	0.24	0.15	-0.11	0.04
Task performance	**0.60*** **	0.07	**0.49*** **	0.02	0.10	-0.03

*p<.05, ** p < .01, ***p<.001

4.4.3 Students' scientific epistemological views and searching strategies

To further explore whether students' SEVs are related to searching strategies, correlations between SEVs, searching strategies and task performance are presented in Table 4.9. Students' responses concerning invented and creative nature of science were negatively and significantly related to Webpage adoption ($r= -0.35$, $p<.01$) and total depth of Webpage adoption ($r= -0.29$, $p<.05$). Students having constructivist-oriented approach to the invented and creative nature of scientific knowledge might intend to create individual explanations and imaginations instead of finding a lot of other solutions on the Internet. Thus, as searching on the Internet, they might try to assimilate the content presented in fewer pages and apply it to science-related task instead of navigating deeply and adopting more Webpages for science-related task. On the contrary, empiricist-oriented students may search more and deeply to find a lot of resources to support their explanations for science-related task. Another scale, changing and tentative features of scientific knowledge, was significantly correlated to time of scanning Webpage ($r=0.36$, $p<0.01$) and time of Webpage adoption ($r=0.29$, $p<0.05$); also, it was significantly and positively related to task performance ($r=0.46$, $p<0.001$). That is, the results showed that students might spend more time scanning selected and adopted Webpages if they believe the feature about uncertainty of scientific knowledge. In sum, the results showed that students with advanced beliefs in some scales (i.e., invented and creative nature of science and changing and tentative features of scientific knowledge) of SEVs might carefully inspect the matter of information in Webpages instead of choosing more Webpages with deeper layer to find exact answer for performing science-related task.

Table 4.9. Inter-correlation between strategies of searching strategy, amount of information retrieval, Task performance and SEVs (n=62)

	Invented and creative	Theory-laden	Changing and tentative	Social negotiations	Cultural impacts
Number of keywords	0.02	-0.11	0.05	0.09	-0.20
Time of browsing result (sec)	0.07	0.06	0.10	0.13	-0.02
Time of scanning Webpage (sec)	0.05	0.11	**0.36****	0.08	0.09
Number of Webpage	-0.17	-0.11	0.14	0.12	0.02
Total depth of Webpage	-0.19	-0.15	0.10	0.08	-0.06
Revisited Webpage	0.06	0.05	0.06	-0.06	-0.05
Webpage adoption	**-0.35****	-0.12	-0.06	0.01	-0.06
Total depth of Webpage adoption	**-0.29***	-0.12	-0.14	-0.01	-0.19
Time of Webpage adoption (sec)	0.07	0.08	**0.29***	0.05	0.03
Amount of information	-0.17	-0.01	0.13	-0.10	0.02
Task performance	0.04	0.15	**0.46*****	0.03	0.16

*p<.05, ** p < .01, ***p<.001

4.4.4 Correlation between ICs and SEVs

The correlations among scales of SEVs and those of ICs are shown in Table 4.10. It can be found that "The invented and creative nature of science", "Theory-laden exploration", "The changing and tentative features of scientific knowledge" and "The cultural impacts" were significantly correlated with "Multiple sources as correctness". Three dimensions of SEVs (i.e., the changing and tentative features of scientific knowledge, the role of social negotiations, the cultural impacts) were significantly correlated with "Content as usefulness". The results were consistent with previous literatures that students with constructivist-oriented beliefs may have advanced information commitments displayed as experts (Tsai, 2004a, 2004b).

Table 4.10. Intercorrelations among SEVs and ICs (n=62)

	SEVs				
ICs	IC	TL	CT	SN	CU
MS	**.26***	**.36****	**.50*****	.22	**.35****
AU	-.15	-.05	.03	.07	.07
CO	.20	.24	**.41*****	**.31***	**.32***
TE	-.20	.08	.04	.07	.18
EL	.22	.08	.16	.17	.22
MA	-.10	.12	.10	.12	.18

*p<.05, ** p < .01, ***p<.001

Notes:

IC: The invented and creative nature of science

TL: The theory-laden exploration

CT: The changing and tentative features of scientific knowledge

SN: The role of social negotiations

CU: The cultural impacts

4.4.5 Regression analysis of predicting students' task performance

The stepwise regression method was employed to predict students' task performance. Predictors included Internet experience, academic achievement, all of scales in ICs and SEVs, and all of indicators about searching strategies. The final model as shown in Table 4.11, among all the searching strategies, ICs and SEVs variables, only two variables (i.e., multiple sources as correctness and content as usefulness) entered the final model in predicting students' task performance. It reveals that students who deemed multiple sources and content as more important criteria to access Web-based information, would gain fruitful outcomes from Internet-based learning activities regarding science. However, students' prior knowledge and factors of SEVs failed to enter the final regression model finally. This result indicated that students' information commitments, such as multiple sources and content, might effectively predict their task performance while engaging in the Internet-based learning environments.

Table 4.11. Multiple Regression models of predicting students' science-related task performance

Model	Predictors	B	Std. Error	Beta	R-square
1	constant	-7.71	1.73		
	Multiple sources as correctness	2.12	0.36	0.60***	0.35***
2	constant	-12.50	2.29		
	Multiple sources as correctness	1.72	0.37	0.49***	
	Content as usefulness	1.32	0.44	0.31**	0.43***

*p<.05, ** p < .01, ***p<.001

4.4.6 Regression models of predicting students' task performance by examining the interaction between SEVs and ICs

When students were engaged in science-related task on the Internet, what was the role of SEVs and ICs ? To explore how both information commitments and scientific epistemological views interact with students' task performance, this study conducted dummy regression models for further analysis. According to Tsai's (2004) assertions, students' epistemologies and information commitments may influence their Internet-based learning outcomes; meanwhile, epistemological beliefs may guide how information commitments work. Hence, this study transformed score of six indicators of ICs into dummy variables (0 below the mean as low ICs and 1 above the mean as high ICs) to separately moderate the relationship between scales of SEVs and task performance by the method of force-entered regression. Tables 4.12 to 4.16 show the thirty regression models. Four among these thirty regression models showed a statistic interaction between SEVs and ICs to predict task performance as following:

A. Model predicting the task performance by examining the interaction between IC and MS (IC×DMS), shown in Table 4.12.

B. Model predicting the task performance by examining the interaction between CT and AU (CT×DAU), shown in Table 4.14.

C. Model predicting the task performance by examining the interaction between CT and CO (CT×DCO), shown in Table 4.14.

D. Model predicting the task performance by examining the interaction between CU and MS (CU×DMS), shown in Table 4.16.

Table 4.12. Multiple Regression models of predicting students' science-related task performance and interaction between SEVs (Invented and creative) and different approaches of ICs

	Predictors	B	Std. Error	Beta	R-square
Invented and Creative (IC)					
1	constant	-0.90	2.20		
	IC	0.31	0.49	0.09	
	DMS	10.32	3.26	2.01**	
	IC×DMS	-1.47	0.70	**-1.39***	**0.46*****
2	constant	-1.12	2.95		
	IC	0.73	0.63	0.20	
	DAU	6.43	4.37	1.24	
	IC×DAU	-1.33	0.93	-1.20	-0.01
3	constant	1.98	2.32		
	IC	-0.19	0.51	-0.05	
	DCO	3.51	3.87	0.67	
	IC×DCO	-0.11	0.82	-0.10	0.28***
4	constant	-2.51	3.23		
	IC	1.01	0.67	0.28	
	DTE	7.97	4.39	1.55	
	IC×DTE	-1.71	0.94	-1.53	0.01
5	constant	-2.94	3.17		
	IC	1.11	0.70	0.31	
	DEL	9.24	4.38	1.80*	
	IC×DEL	-1.90	0.94	-1.81*	0.03
6	constant	3.312	3.46		
	IC	-0.17	0.73	-0.05	
	DMA	-2.60	4.50	-0.49	
	IC×DMA	0.48	0.96	0.43	-0.04

*p<.05, ** p < .01, ***p<.001

Table 4.13. Multiple Regression models of predicting students' science-related task performance and interaction between SEVs (Theroy-laden) and different approaches of ICs

Theory-laden (TL)					
1	constant	-0.67	1.62		
	TL	0.28	0.39	0.10	
	DMS	7.15	2.45	1.39**	
	TL×DMS	-0.84	0.55	-0.79	0.43***
2	constant	-1.05	1.97		
	TL	0.74	0.44	0.27	
	DAU	4.11	3.21	0.79	
	TL×DAU	-0.88	0.71	-0.77	0.001
3	constant	0.63	1.63		
	TL	0.11	0.38	0.04	
	DCO	3.65	2.91	0.70	
	TL×DCO	-0.17	0.63	-0.15	0.28***
4	constant	-0.90	2.18		
	TL	0.73	0.49	0.27	
	DTE	2.87	3.13	0.56	
	TL×DTE	-0.66	0.70	-0.59	-0.01
5	constant	-2.29	2.04		
	TL	1.02	0.47	0.38*	
	DEL	6.47	3.09	1.26*	
	TL×DEL	-1.39	0.69	-1.27*	0.05
6	constant	1.58	2.39		
	TL	0.22	0.54	0.08	
	DMA	-1.98	3.17	-0.37	
	TL×DMA	0.36	0.71	0.31	-0.02

*p<.05, ** p < .01, ***p<.001

Table 4.14. Multiple Regression models of predicting students' science-related task performance and interaction between SEVs (changing and tentative) and different approaches of ICs

Changing and Tentative (CT)					
1	constant	-3.76	2.94		
	CT	0.98	0.68	0.24	
	DMS	5.02	4.16	0.98	
	CT×DMS	-0.45	0.90	-0.44	0.44***
2	constant	-9.71	2.57		
	CT	2.59	0.56	0.64***	
	DAU	10.53	4.58	2.02*	
	CT×DAU	-2.25	0.97	**-2.07***	**0.24*****
3	constant	-0.80	2.32		
	CT	0.43	0.51	0.11	
	DCO	-8.49	4.13	-1.62*	
	CT×DCO	2.29	0.86	**2.17****	**0.44*****
4	constant	-4.59	2.91		
	CT	1.46	0.61	0.36*	
	DTE	-4.43	4.47	-0.86	
	CT×DTE	1.00	0.95	0.91	0.19**
5	constant	-7.20	2.88		
	CT	2.05	0.63	0.51*	
	DEL	2.16	4.61	0.42	
	CT×DEL	-0.46	0.98	-0.44	0.17**
6	constant	-4.80	3.23		
	CT	1.56	0.68	0.39*	
	DMA	-2.77	4.43	-0.52	
	CT×DMA	0.54	0.94	0.48	0.18**

*p<.05, ** p < .01, ***p<.001

Table 4.15. Multiple Regression models of predicting students' science-related task performance and interaction between SEVs (social negotitation) and different approaches of ICs

Social negotiation (SN)					
1	constant	-0.66	2.59		
	SN	0.26	0.57	0.06	
	DMS	8.69	3.73	1.69*	
	SN×DMS	-1.14	0.80	-1.06	0.43***
2	constant	0.24	2.98		
	SN	0.42	0.65	0.10	
	DAU	4.95	5.44	0.95	
	SN×DAU	-1.01	1.16	-0.92	-0.03
3	constant	3.86	2.63		
	SN	-0.61	0.58	-0.15	
	DCO	-0.34	4.34	-0.07	
	SN×DCO	0.72	0.92	0.66	0.29***
4	constant	2.54	3.95		
	SN	-0.05	0.83	-0.01	
	DTE	-1.55	5.15	-0.30	
	SN×DTE	0.34	1.10	0.31	-0.04
5	constant	-2.48	3.74		
	SN	1.01	0.83	0.25	
	DEL	8.10	5.05	1.58	
	SN×DEL	-1.66	1.09	-1.56	0.00
6	constant	5.65	3.98		
	SN	-0.68	0.86	-0.17	
	DMA	-6.49	5.07	-1.22	
	SN×DMA	1.33	1.09	1.18	-0.02

*p<.05, ** p < .01, ***p<.001

Table 4.16. Multiple Regression models of predicting students' science-related task performance and interaction between SEVs (cultural impacts) and different approaches of ICs

Cultural impact (CU)					
1	constant	-1.13	1.76		
	CU	0.36	0.38	0.11	
	DMS	11.31	3.51	2.20**	
	CU×DMS	-1.63	0.72	**-1.59***	**0.46*****
2	constant	-1.52	2.80		
	CU	0.79	0.59	0.24	
	DAU	3.05	4.12	0.59	
	CU×DAU	-0.60	0.85	-0.57	-0.01
3	constant	-0.94	2.06		
	CU	0.44	0.44	0.14	
	DCO	6.72	3.73	1.28	
	CU×DCO	-0.80	0.76	-0.76	0.29***
4	constant	-0.02	2.77		
	CU	0.50	0.59	0.15	
	DTE	-0.41	4.15	-0.08	
	CU×DTE	0.06	0.86	0.06	-0.03
5	constant	-3.23	2.54		
	CU	1.16	0.55	0.35	
	DEL	8.64	4.22	1.68*	
	CU×DEL	-1.75	0.87	-1.71*	0.04
6	constant	2.34	3.42		
	CU	0.04	0.73	0.01	
	DMA	-4.03	4.26	-0.76	
	CU×DMA	0.76	0.89	0.71	-0.01

*p<.05, ** p < .01, ***p<.001

The interactions shown in models B and C indicated that students holding more constructivist-oriented SEVs (changing and tentative) performed better with proper ICs (high ICs in content and low ICs in authority). Situations of model B and C could be illustrated as Figure 4.1 and 4.2. Students possessing advanced scientific epistemological beliefs (i.e., changing and tentative) along with proper information commitments (i.e., low ICs in authority and high ICs in content) might benefit greatly from Internet-based science learning activities.

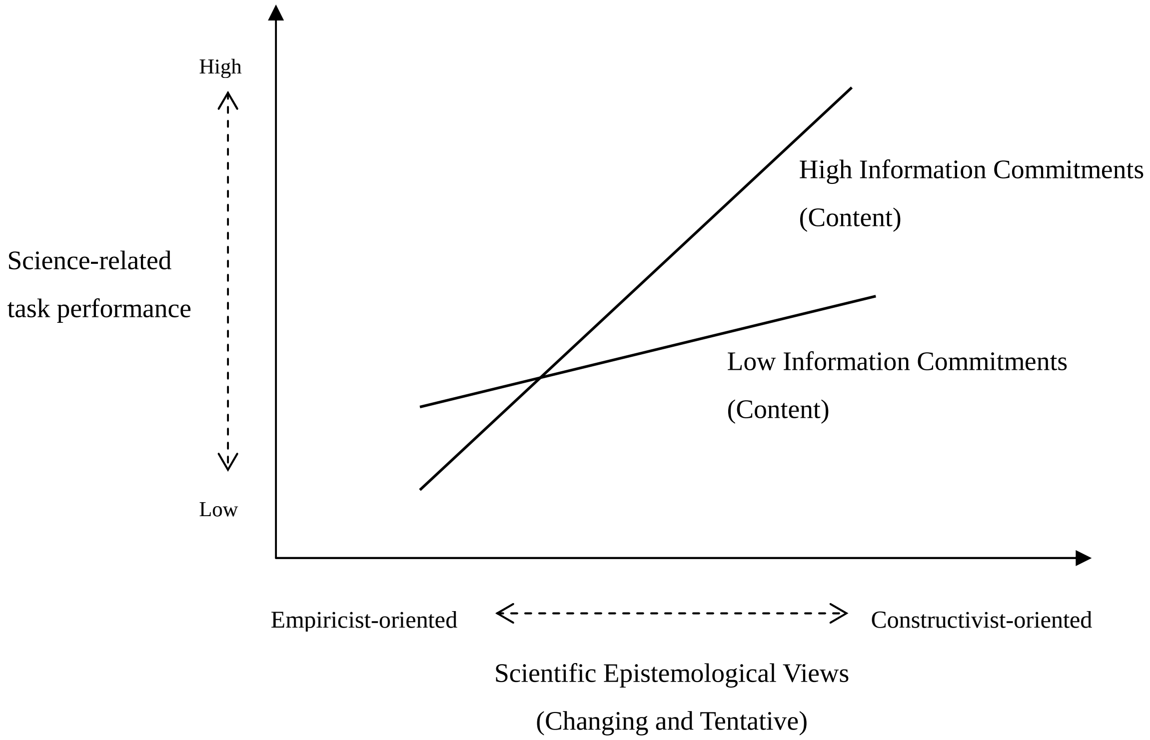


Figure 4.1 Interaction between ICs (Content) and SEVs (Changing and tentative) with science-related task performance

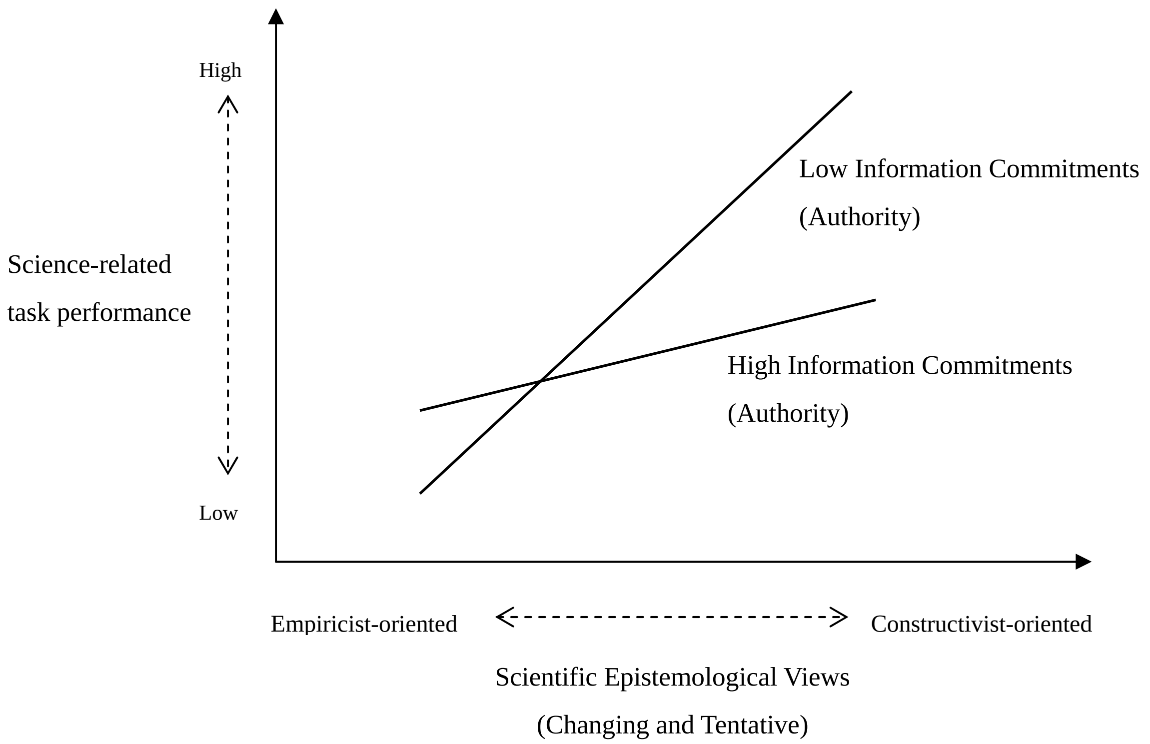


Figure 4.2 Interaction between ICs (Authority) and SEVs (Changing and tentative) with science-related task performance

However, the interactions between IC and MS (model A) as well as CU and MS (model D) showed opposite results that students having more empiricist-oriented SEVs (invented and creative, cultural impacts) performed better with proper ICs (high ICs in multiple sources). Figure 4.3 and 4.4 illustrates the situation of model A and D separately. By refering to the finding of Lazonder (2000) that experts usually needed more time to chose and perform successful strategies as searching on the Internet as novices did,it can be expected that students with high ICs in multiple sources may not have sufficient time on executing multiple sources to find webpages for answering science-related task in this study. The time constraint (i.e., twenty minutes) placed on this study may lead to a contradiction between students' high ICs in multiple sources and science-related task performance. Hence, students having high ICs in multiple sources may need an open-ended Internet learning environment free of time constraint to execute such standard entirely. Moreover, as mentioned in section 4.3, high school students in this study rarely sought other resources to refine task. In other words, they may view multiple sources as finding more Webpages with the most correct answers rather than seeking multiple sources to compare, evaluate and integrate the information for performing science task. Reasons mentioned above may explain the downward trend of task performance when constructivist-oriented SEVs (i.e., IC and CU) interact with high ICs (multiple sources) in the open-ended Internet learning environments within a time constraint.

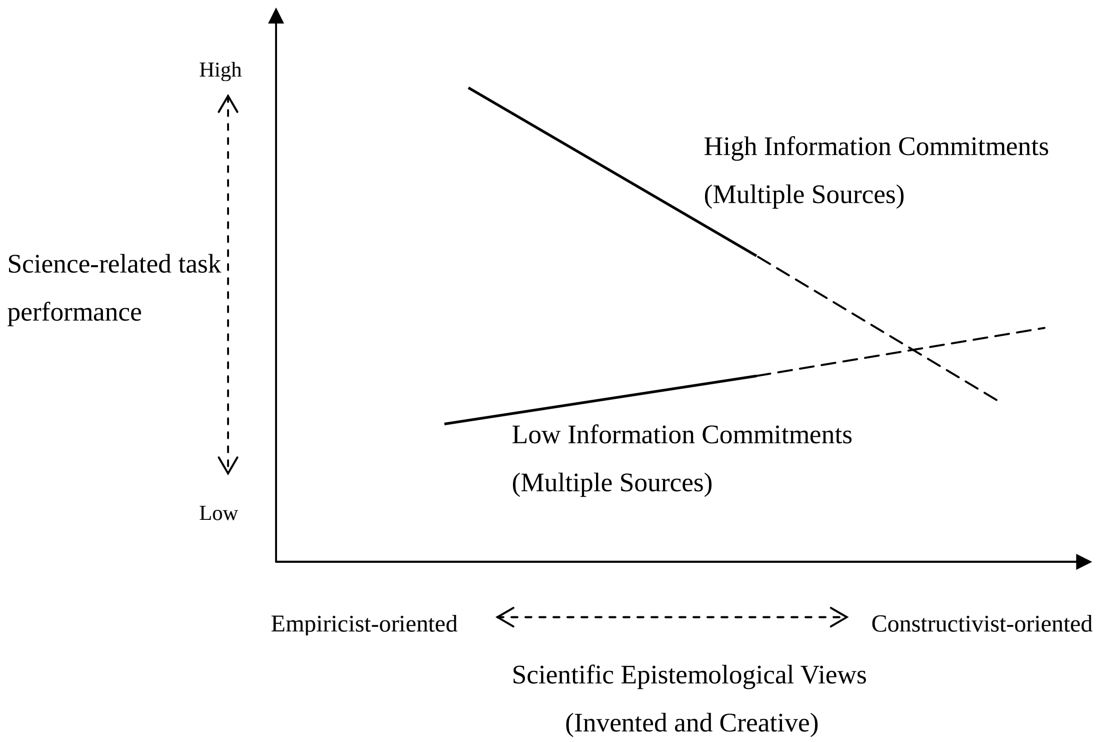


Figure 4.3 Interaction between ICs (Multiple sources) and SEVs (Invented and creative) with science-related task performance

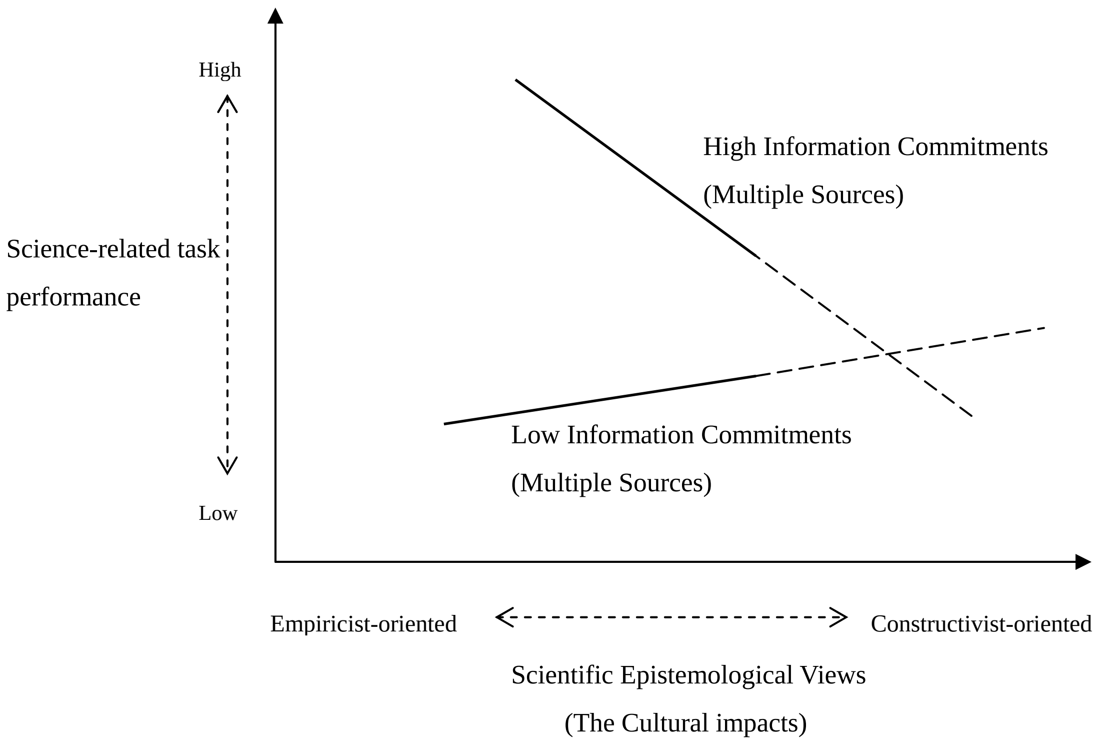


Figure 4.4 Interaction between ICs (Multiple sources) and SEVs (The cultural impacts) with science-related task performance

4.5 Follow-up study – Interview with selected students

In order to acquire a better understanding about the relationships between students' scientific epistemological views and information commitments, this study conducted interviews which mainly followed the research work of Tsai and Liu (2005) and Wu and Tsai (2005). There were two groups categorized by students' sum scores of all SEVs subscales. One was "constructivist-oriented" group categorized by top 10% scores of the SEVs instrument; the other one was "empiricist-aligned" group categorized by bottom 10% scores of the instrument. In each group, four male and four female students were randomly selected to respond to questions about SEVs and ICs. Audio records were transcribed by two trained researchers. Because the interviews were conducted in Chinese-language, all of the data presented in this study had to be transcribed after the main researcher's translation and was further examined by an independent listener. Firstly, eight students in two groups (A, B, C and D categorized as empiricist-oriented group; E, F, G and H categorized as constructivist-oriented group) were interviewed according to the questions employed by Tsai and Liu (2005). Some representative results on each scale are listed in the following:

1. The Invented and creative nature of science:

Student A: Science is that scientists create and always keep looking for the new theory.

Student B: Science is discovered by scientists… but why do they always have new discoveries?

Student H: Scientists, like magicians, seem to image and invent the new scientific theory every day.

2. Theory-laden exploration:

Student B: I think that scientists should have common methods to study science.

Student F: I think that scientists study science with different methods, such as the difference between physicist and mathematician.

Student G: The scientists of different fields must hold different views and ways to approach science.

3. The changing and tentative feature of science knowledge

Student A: I think that scientific knowledge can not be changeable, otherwise there is not a model answer when having an examination

Student D: Scientific knowledge seems to be changeable….. But presenting scientific knowledge should show the last edition, isn't it?

Student H: Science is always changing, because scientists will find new evidence to evidence the new science theory.

4. The role of social negotiation

Student B: The scientific theories were developed by a certain scientist, as if Newton's laws are proposed by Newton.

Student C: I think that science theories are formed after scientists propose sufficient evidences to persuade other scientists in the same field.

Student G: The scientific theories are proposed via a series of discussions and confirmations by a group of scientists, and refined when new evidence is found.

5. Cultural impacts

Student C: The scientific theory under different cultures will have no difference. The formation of scientific theory should not to be influenced by culture.

Student E: I am uncertain whether culture will influence the formation of scientific theory…….But Chinese seems to have different ways of observing the constellation from other countries.

Student G: Scientific knowledge may differ according to different cultures. People in different cultures may hold different customs, opinions and views.

Secondly, eight students were interviewed by the questions employed by Tsai (2004a). Some results on each scale of ICs are listed as following:

Student A: I usually find relevant information by using search engine, online newspaper and library. As finding the most correct information, especially endorsed by someone, I believe it is sufficient to fulfill my initial purpose.

Student B: I usually search information via search engine. I will view the content of many related Webpages to find relevant materials. If some websites make me find a lot of relevant information more easily, its content may be useful for me.

Student C: I will utilize the search engine to look for the materials first. Or, I post questions on the relevant discussion forums to wait for reply, or find previous posts related to my questions.

Student E: I will make use of a lot of keywords to look for the materials, and see other relevant keywords or contents involved in Webpages. I suggest that I can find the correct answer in this way. Basically, I think that any information can be found by utilizing search engine.

Student H: There is a lot of information on the web, but it might not be true. So I will usually look over the content of the webpage and determine whether it is a correct answer. Moreover, I may search other resources to find the best solution.

According to the eight students' interview responses, Table 4.13 shows the results of SEVs and ICs. For example, student D held CT as constructivist-oriented SEVs and had AU, CO, TE and MA as ICs; student F viewed IC, TL and CT as constructivist-oriented SEVs as well as believed CO, EL and MA as ICs. It was found that students in the constructivist-oriented group, compared with those in the empiricist-oriented group, displayed the majority of constructivist-oriented epistemological views toward science. According to Table 4.13, three students in the empiricist-oriented group perceived AU as the standard for correctness while there is only a student in the constructivist-oriented group. All of students in the constructivist-oriented group viewed content as an important standard for usefulness. In addition, there were two students in the constructivist-oriented group possessing elaboration as searching strategy while there was none in the empiricist-oriented group. Thus, students holding constructivist-oriented SEVs had more proper ICs such as less authority as correctness, more content as usefulness and more elaboration as searching strategies than those in the other group. In other words, the students of constructivist-oriented SEVs may deal with online materials by content as standard and elaboration as strategies whereas empiricist-oriented students may rely on the authority. The results may differ from the quantitative findings shown in the Table 4.10 that multiple sources and content are mainly related to SEVs. However, even in the empiricist-oriented group, students still held constructivist-oriented approaches on a few SEVs dimensions. The results indicated that students in the empiricist-oriented group were not totally empiricist. That is, students may simultaneously possess mixed epistemological views (both empiricist- and constructivist-oriented approach) toward science.

Table 4.13. Students' interview results of SEVs and ICs

Group	Student	Gender	Interview for constructivist-oriented SEVs	Interview for ICs
Empiricist-oriented	A	Female	IC SN	MS, AU, CO, MA
	B	Male	IC CU	CO, TE, MA
	C	Male	SN	MS AU, TE
	D	Female	CT	AU, CO, TE, MA
Constructivist-oriented	E	Female	IC, CT, CU	CO, TE, EL, MA
	F	Male	IC, TL CT	CO, EL, MA
	G	Female	TL IC, CT, CU	MS, AU, CO, TE
	H	Male	IC, CT, SN	MS, CO, MA

And, most of the interviewed students shared a consistent point of view (7/8 students across groups), considering "content as the usefulness" to be the most important standard for examining the quality of information while searching on the Web. Based on the interview responses above, students may simultaneously possess somewhat contradictory ICs (i.e., multiple sources versus authority or elaboration versus match) simultaneously along with dissimilar SEVs while searching online resources for fulfilling ones' needs. Table 4.13 displays complex combinations according to their interview results about SEVs and ICs. That is, students may simultaneously hold diverse SEVs and ICs when engaging in Internet-based science learning activities.

Moreover, high school students may view multiple sources as necessary for searching; however, they are only to find the best matched answer instead of judging information presented in multiple sources. For example, Student E and H, also mentioned about the importance of multiple sources, but they believe that they need it in some special situations. The findings of interview results may slightly explain the results revealed in section 4.4.6. Students may deem multiple sources as a way to find "useful" solutions rather than possible "correct" solutions. In addition, students with advanced SEVs preferred to simplify their searching process and focus on the content of particular Webpages. Hence, a consistency between quantitative results and qualitative details may, to a certain extent, also support previous findings reported in the other parts of section four in this chapter.

Chapter 5 – Discussion and Conclusion

As the Internet is often the starting point for accessing information resources, it is important to understand more about the epistemological processes involved when students construct individual understanding of Web-based information (Hofer, 2004; Linn, 2000, 2003). In the present study, both quantitative and qualitative methods were employed to explore high school students' searching strategies, information commitments and scientific epistemological views. Most importantly, relevant epistemological issues were conducted in an Internet-based context, which responded to the concern that epistemological theories should be investigated through questionnaires, interviews and also in context (Hofer, 2004).

To explore high school students' searching strategies, this study employed 'Navigation Flow Map' method proposed by Lin and Tsai (2005), and further proposed three indicators for assessing time of browsing result, time of scanning Webpage and time of Webpage adoption, respectively. As searching science-related information on the Internet, we found that high school students, in the present study, seldom revisited previous Webpages or refined previous works. They intended to find a best-match solution rather than collect, compare and integrate online information with individual explanation for a better product. However, students' evaluation of online information may reflect their metacognitive strategies and influence their Internet-based learning performances while searching on the Internet (Tsai & Tsai, 2003). Thus, shortness of metacognitive searching strategies (i.e., revisiting Webpage and refining previous works), educators have to help high school students develop proper strategies to acquire relevant information and judge its merits. By gender comparisons on the features of searching strategies, the results revealed that female students intend to navigate more deeply into different sites for collecting answer than males did. It may contradict some previous findings that male students possess more positive attitudes, higher confidence and advanced skills toward using the computer or Internet (Large et al., 2002; Tsai, Lin & Tsai, 2001; Volman & van Eck, 2001). However, recent studies have found that female students possess higher Internet self-efficacy which may affect their persistence on learning and usage of the Internet system (Tsai & Lin, 2004; Tsai & Tsai, 2003). That is, as searching on the Internet, female students may spend more time on searching and navigate more Webpages deeply to sustain their Internet-based learning activities. Due to the lack of related research for exploring gender difference in online searching strategies (Kuiper, Volman & Terwel, 2005), the findings of this study may be helpful for further research.

Two indicators, time of scanning Webpage and time of Webpage adoption, were related to students' task performance. Students who spent more time on inspecting the contents involved in Webpages may benefit greatly from the searching process. According to the research of Hoffman et al. (2003), students' engagement with high level of searching strategies such as browsing the content and reading information related to the matter of science-related subject may help them develop accurate and in-depth science conceptual understanding. However, in a situation with the time constraint, a careful examination of the content may cost much time and careful time management in the whole searching process may be crucial to successful searching and superior learning. In this study, students were asked to explain the formation of nuclear power by searching resources on the Internet. They not only had to find relevant resources, but also comprehend the information presented on the Webpages they chose. Thus, students' task performance may somewhat reflect their understandings of this science-related topic and represent their learning outcome partially.

The results from the exploratory factor analysis confirmed that ICs survey was suitable to assess high school students' information commitments. The quantitative (and interview) results revealed that high school students employed mixed standards while dealing with information on the Internet (e.g., significant correlations between authority and content), which were parallel to the findings of Wu and Tsai (2005). The correlations between SEVs, ICs, searching strategies and science learning outcomes suggested that these epistemology-related issues might affect students' searching strategies and learning outcome, as proposed by Tsai, 2004a, 2004b, Wu and Tsai, 2005. The main findings derived from the present study are shown in Figure 5.1. Also, the results further revealed that students' usage of Internet as an effective tool for learning (i.e., searching factual information) involved numerous epistemological standards. For instance, students having constructivist- oriented SEVs (e.g., changing and tentative) might utilize "multiple sources" and "content" as proper standards while searching on the Internet. Or, students holding constructivist-oriented views about social negotiation might mainly view "content" as an evaluative standard. Such mixed combinations of SEVs and ICs were also shown in students' interview responses. For example, as shown in Table 4.13, student H having constructivist-oriented "inevented and creative", "changing and tentative" and "social negotiation", viewed "multeple sources", "content", and "match" as important standards and strategies for judging online information. Thus, students may have a host of epistemological judgments as well as the mixed combinations while employing Internet as a medium for learning science.

According to the assumptions and empirical results proposed by previous research, Figure 5.2 shows main research contributions on SEVs, ICs, searching strategies and Internet-based science learning performance in the present study. First, the CT dimension of SEVs was positively related to CO and MS scales of ICs, which corresponded to the assertion that SEVs may guide students' ICs (Tsai, 2004a, 2004b). Second, the CO and MS scales of ICs were positively related to students' Internet-based science learning performance, which supported the assertion that ICs may affect students' Internet-based science learning performance (Tsai, 2004a, 2004b; Wu & Tsai, 2005). Finally, the CT dimension of SEVs was positively related to students' Internet-based science learning performance, which evidenced the assertion that SEVs may affect students' Internet-based learning performance (Tsai, 2004a, 2004b). Although previous studies (i.e., Wu and Tsai, 2005; Hoffman et al., 2003) have investigated the relationships between ICs, searching strategies and Internet-based science learning performance by quantitative (i.e., structural equation modeling) and qualitative analyses (i.e., in-depth interviews), students' features of searching strategies, extracted from searching behaviors by NFM method, can more authentically represent their explicit features in a Internet-based learning environment. Thus, the findings in this study may profoundly explore the connections between implicit components (i.e., SEVs and ICs) and explicit components (i.e., searching strategies) further. However, more careful examinations into the structure of the relationships between SEVs, ICS, searching strategies and Internet-based science learning performances are needed by other statistical methods such as structural equation modeling. It may further confirm the influences of epistemological beliefs on students' searching strategies and Internet-based learning performances.

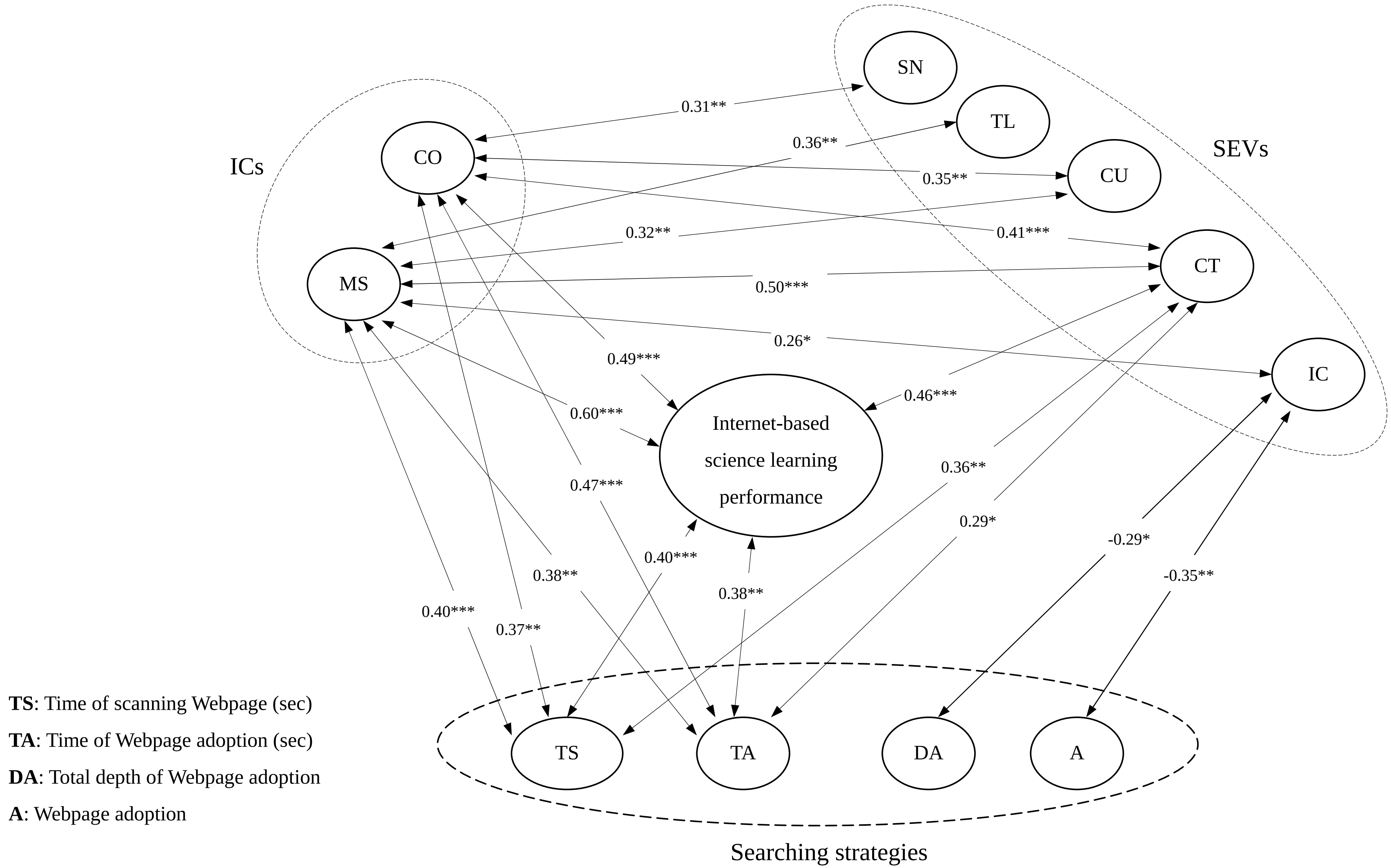


Figure 5.1 Interrelationships between SEVs, ICs, searching strategies and Internet-based science learning performance

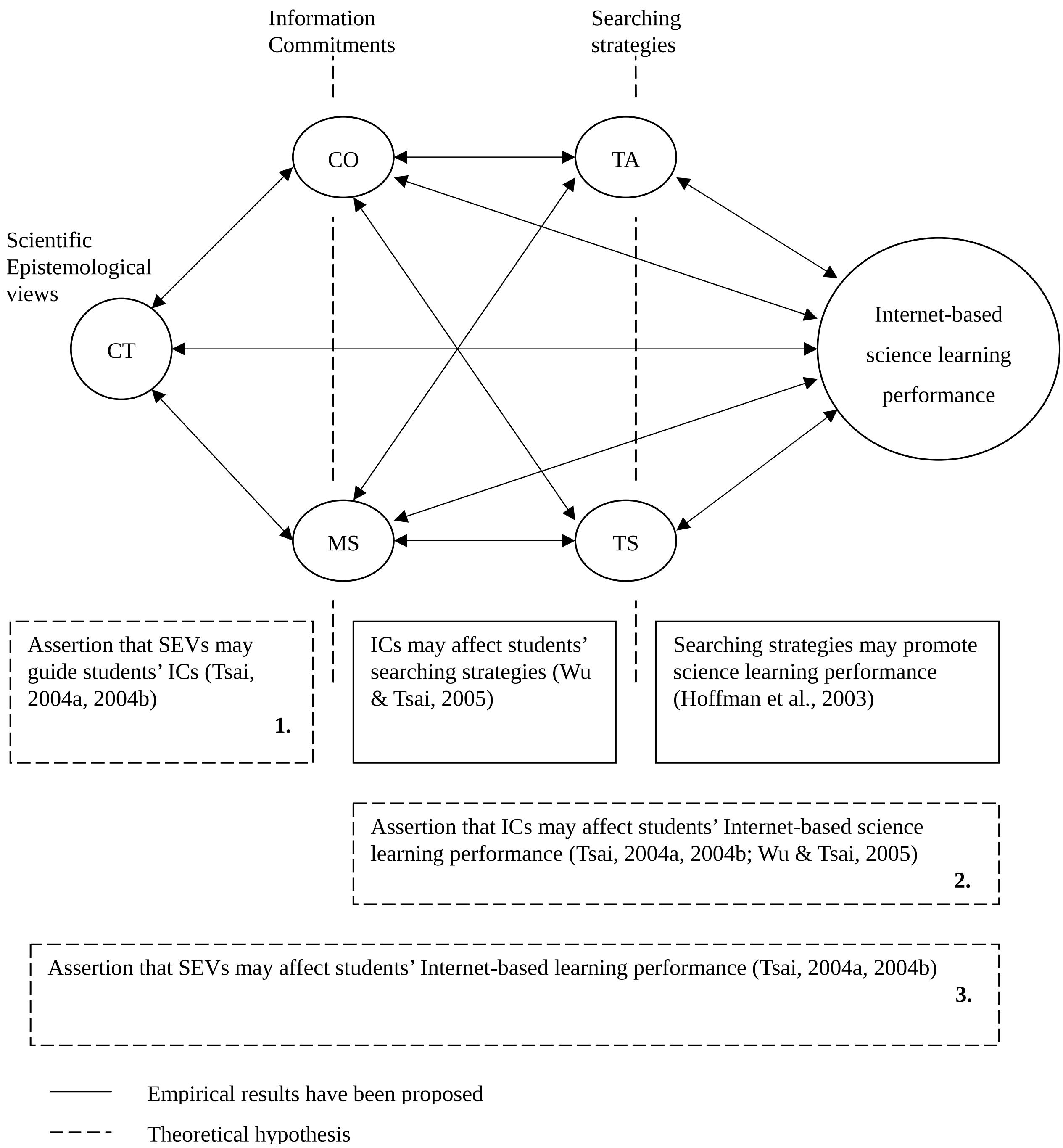


Figure 5.2 Contributions to the research about SEVs, ICs, searching strategies and Internet-based science learning performance in the present study

Besides, it may be interesting to explore the most important variables that can account for students' Internet-based science learning performance. Two variables of ICs, multiple sources and content, entered the final regression model of predicting students' score. According to Tsai's (2004a) assertions that ICs are involved as a part of epistemological beliefs, the results of regression model indicated that ICs had more direct influences on predicting Internet-related learning performance. Moreover, the results of section 4.4.6 also supported his suggestion that students' epistemological beliefs and information commitments may simultaneously relate to their Internet-based learning outcomes. That is, students' constructivist-oriented SEVs (i.e., changing and tentative) may enhance their Internet-based science learning performance along with their proper ICs (i.e., low ICs in authority and high ICs in content). In conclusion, as the results presented above, it can be proposed that students, when searching on the Internet, may employ different ICs to judge the accuracy and usability of accessing Web-based information firstly; then, they may approach the nature of scientific knowledge based upon their SEVs for dealing with the encountering science-related information presented on the Internet.

As searching information on the Internet, meaningful learning will result extensively from meaningful searching (Jonassen et al., 2003). Previous research also suggested the needs that students' searching strategies should be enhanced by monitoring cognitive and metacognitive skills (Lazonder, 2000; Tsai & Tsai, 2003). However, as the results found in this study, we further proved the needs that students' searching strategies should be incorporated with epistemology-related concerns, namely, both SEVs and ICs while searching scientific information for fulfilling their philosophical demands for scientific knowledge. Thus, educators need to pay particular attentions to help students acquire proper ICs and constructivist-oriented

SEVs. In addition, the complex correlations between nine searching indicators and other variables further confirmed the effectiveness of using the NFM method for analyzing searching behaviors. In the future, there is a need to examine different combinations of the features involved in searching strategies.

This study also encountered a dilemma about whether placing time constraint or not. Although some students advanced the time of accomplishing the task, the results showed the gap between students' explicit searching strategies and implicit ICs might be widened because of the limited time of searching process. Thus, a longer period of time (e.g., more than twenty minutes) may take into account in the design of future research. It allows educators and researchers to track a user's searching process in a graphical and quantitative way to gain insights into the cognitive and procedural strategies that students are using in an open-ended Internet-based environment without relying on database of recording navigation logs for analysis. The NFM method allows researchers synchronously record searchers' on-screen activities without interrupting their searching behaviors for later analysis. It avoids searchers knowing they were being observed and changing their actual searching approaches by the way of video recording (Drabenstott, 2003). The recorded on-screen Web activities not only help researchers understand the way searchers access online information, but also the sites they prefer to glean information by interpreting its properties of the authority and the origin. Moreover, the NFM-based data may also yield new insights into better educational practices to enhance student's web-based learning through mastery of more efficient Web-search strategies. Furthermore, the cumulative data from more extensive research studies, using the NFM method, may provide refined criteria for evaluating Web-based learning environments and yield more valid criteria for judging student proficiency as derived from research-based evidence. However, the NFM method was very time consuming in coding searchers' qualitative Web activities and may cause more man-made errors for large scale analysis. As Chen, Han and Yu (1996) claimed that the data mining is an available technique of capturing Web users' access patterns in the information providing environments (e.g., Internet, World Wide Web), namely, *mining path traversal patterns* which are similar to different combinations of searching strategies proposed in this study. Consequently, by use of such technology-supported software (i.e., data mining for exploring the Web users' browsing tactics), it may be potentially powerful to analyze students' searching strategies along with NFM method.

Furthermore, students' searching approaches or patterns (e.g., exploration, match or combined) including nine features of searching strategies may be explored by the method of cluster analysis. Thus, students with different searching approaches may hold various scientific epistemological views and information commitments while searching and learning in the Internet-based science learning environments. The topic employed in the present study is more fact-based, whereas scientific knowledge is needed ones to be imaged, invented, created and negotiated. Hence, to explore the role of students' scientific epistemological views in the Internet-based learning environments, researchers need to conduct students to a more research-oriented and open-ended issue regarding science in the future. In addition, students' science task performance may be unable to adequately demonstrate their understandings about the science topic and represent Internet-based science learning outcomes. Based on the perspectives of constructivism, every individual may have different ways of organizing knowledge and then develop typical cognitive structure which account for learning outcomes. According to the review of Tsai and Huang (2002), they addressed the flow map method as an effective tool to represent learners' process of knowledge acquisition and cognitive structures. By probing students' cognitive structures, researchers can assess their learning outcomes through the examination on the sequential and network features between concepts. Thus, the employment of flow map method to represent students' Internet-based science learning outcomes should be taken into account in the future. Finally, the validity and reliability of the nested relationships between SEVs, ICs, searching approaches and Internet-based science learning outcomes should be confirmed more rigorously. The usage of structural equation modeling (SEM) techniques may be powerful to assess the quality of theoretical frameworks and predictive relationships among constructs.

References

American Association for the Advancement of Science. (1990). *Science for all Americans*. New York: Oxford University Press.

Abd-El-Khalick, F., Bell, R. L., and Lederman, N. G. (1998). The nature of science and instructional practice: making the unnatural natural. *Science Education, 82*, 417-436.

Anderson, O. R., & Demetrius, O. J. (1993). A flow-map method of representing cognitive structure based on respondents' narrative using science content. *Journal of Research in Science Teaching, 30*, 953-969.

Bilal, D. (2000).Children's use of the Yahooligans! Web search engine: I. Cognitive, physical, and affective behaviors on fact-based search tasks. *Journal of the Americam Society for Information Science, 51*, 646-665.

Bilal, D. (2001). Children's use of the Yahooligans! Web search engine: II. Cognitive and physical behaviors on research tasks. *Journal of the American Society for Information Science, 52,* 118-136.

Bilal, D. (2002). Children's use of the Yahooligans! Web search engine. III. Cognitive and physical behaviors on fully self-generated search tasks. *Journal of the Americam Society for Information Science, 53,* 1170-1183.

Bilal, D., & Kirby, J. (2002). Differences and similarities in information seeking: children and adults as Web users. *Information Processing & Management, 38,* 649-670.

Buehl, M. M., & Alexander, P. A. (2001). Beliefs about academic knowledge. *Educational Psychology Review, 13,* 385-418.

Buehl, M. M., Alexander, P. A., & Murphy, P. K. (2002). Beliefs about schooled knowledge: Domain specific or domain general? *Contemporary Educational*

Psychology, 27, 415-449.

Burtis, P. J. (1990). *Children's implicit theories of learning in computer-supported intentional learning environment*, Technical Report on Computer Supported Intentional Learning Environment Project. The Ontario Institute for Studies in Education, Toronto, Canada.

Calcaterra, A., Antonietti, A., & Underwood, J. (2005). Cognitive style, hypermedia navigation and learning. *Computers & Education, 44*, 441-457.

Carey, S., Evans, R., Honda, M., Jay, E., & Uuger, C. (1989). An experiment is when you try it and see if it works - A study of grade-7 students understanding of the construction of scientific knowledge. *International Journal of Science Education, 11*, 514-529.

Chan, C. K. K., & Sachs, J. (2001). Beliefs about learning in children's understanding of science texts. *Contemporary Educational Psychology, 26*, 192-210.

Chang, K. E., Sung, Y. T., & Chen, S. F. (2001). Learning through computer-based concept mapping with scaffolding aid. *Journal of Computer Assisted Learning, 17*, 21-33.

Chen, M.-S., Han, J., and Yu, P. S. (1996). Data Mining: an overview from database perspective. *IEEE Trans. on Knowledge and Data Engineering*, *8*, 866-883.

Chiu, C. H. (2002). The effects of collaborative teamwork on secondary science. *Journal of Computer Assisted Learning, 18*, 262-271.

Chiu, C. H., Huang, C. C., & Chang, W. T. (2000). The evaluation and influence of interaction in network supported collaborative concept mapping. *Computers & Education, 34*, 17-25.

Chou, C., & Tsai, C. C. (2002). Developing web-based curricula: issues and challenges. *Journal of Curriculum Studies, 34*, 623-636.

Clark, R. E. (1983). Reconsidering research on learning from media. *Review of*

Educational Research, 53(4), 445-459.

Cobern, W. W. (1993). Contextual constructivism: the impact of culture on the learning and teaching of science. In K. Tobin (ed.), *The Practice of Constructivism in Science Education*, (pp. 39-50). Hillsdale, New Jersey: LEA.

Cress, U., & Knabel, O. B. (2003). Previews in hypertexts: effects on navigation and knowledge acquisition. *Journal of Computer Assisted Learning, 19,* 517-527.

Davis, E. A. (2003). Understanding dimensions of middle school students' beliefs about scientific knowledge and science learning. *International Journal of Science Education, 25*, 439-468.

Drabenstott, K. M. (2003). Do nondomain experts enlist the strategies of domain experts? *Journal of the American Society for Information Science and Technology, 54-9*, 836-854.

Eklund-Myrskog, G. (1998). Students' conceptions of learning in different educational contexts. *Higher Education, 35,* 299-316.

Eveland W. P., & Dunwoody, S. (2000). Examining information processing on the World Wide Web using think aloud protocols. *Media Psychology, 2,* 219-244.

Fischer, F., Troendle, P., & Mandl, H. (2003). Using the Internet to improve university education: Problem-oriented web-based learning with MUNICS. *Interactive Learning Environments, 11*, 193-214.

Ford, N., Miller, D., & Moss, N. (2003). Web search strategies and approaches to studying. *Journal of the American Society for Information Science and Technology, 54*, 473-489.

Hatcher, L. & Stepanski, E. J. (1994). *A step-by-step approach to using the SAS system for univariate and multivariate statistics*. Cary, NC: SAS Institute.

Hess, B. (1999). Graduate student cognition during information retrieval using the World Wide Web: a pilot study. *Computers & Education, 33,* 1-13.

Hill, J. R. (1999). A conceptual framework for understanding information seeking in open-ended information systems. *Educational Technology Research & Development, 47,* 5-27.

Hölscher, C., & Strube, G. (2000). Web search behavior of Internet experts and newbies. *Computer Networks, 33,* 337-346.

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology, 25,* 378-405.

Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Educational Psychology Review, 13,* 353-383.

Hofer, B. K. (2004). Epistemological understanding as a metacognitive process: Thinking aloud during online searching. *Educational Psychologist, 9*, 43-55.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*, 88-140.

Hoffman, J. L., Wu, H. K., Krajcik, J. S., & Soloway, E. (2003). The nature of middle school learners' science content understandings with the use of on-line resources. *Journal of Research in Science Teaching, 40,* 323-346.

Hsieh-Yee, I. (2001). Research on Web search behavior. *Library & Information Science Research, 23,* 167-185.

Johnson, R. L., Penny, J., and Gordon, B. (2000). The relation between score resolution methods and interrater reliability: an empirical study of an analytic scoring rubric. *Applied Measurement in Education, 13*, 121–138.

Jonassen, D. H. (2000). Computers as mindtools for schools: Engaging Critical Thinking. Columbus, OH: Prentice-Hall.

Jonassen, D. H., Howlan, J., Moore, J., & Marra, R. M. (2003). Learning to solve problems with technology: A constructivist perspective (2nd ed.). Ed. Columbus, OH: Merrill/Prentice-Hall.

King, P. M., & Kitchener, K. S. (2004). Reflective judgment: theory and research on the development of epistemic assumptions through adulthood. *Educational Psychologist, 39,* 5-18.

Kuiper, E., Volman, M., & Terwel, J. (2005). The Web as an information resource in K-12 education: strategies for supporting students in searching and processing information. *Review of Educational Research, 75,* 285-328.

Lamon, M. Chan, C. K. K., Scardamalia, M., Burtis, J., & Brett, C. (April, 1993). *Beliefs about learning and constructive processes in reading: Effects of a computer supported intentional learning environment.* Paper presented at the annual meeting of the American Educational Research Association, Atlanta.

Large, A., Behesti, J., & Rahman, T. (2002). Gender difference in collaborative Web searching behaviour: an elementary school study. *Information Processing and Management, 38*, 427-443.

Lazonder, A. W. (2000). Exploring novice users' training needs in searching information on the WWW. *Journal of Computer Assisted Learning, 16*, 326-335.

Lin, C.- C., and Tsai, C.- C. (2005). *A "navigation flow map" method of representing students' searching strategies on the Web.* Paper presented at 2005 World Conference on Educational Multimedia, Hypermedia & Telecommunications, Montreal, Canada.

Lin, C. Y. (1998). Understanding of the nature of science of senior high school students. *Proceeding of National Science Council, ROC(D), 8*, 33-44.

Linn, M. C. (2000). Designing the Knowledge Integration Environment. *International Journal of Science Education, 22,* 781-796.

Linn, M. C. (2003). Technology and science education: starting points, research programs, and trends. *International Journal of Science Education, 25*, 727-758.

Linn, M. C., Clark, D., & Slotta, J. D. (2003). WISE design for knowledge integration. *Science Education, 87*, 517-538.

Lumpe, A. T., & Butler, K. (2002). The information seeking strategies of high school science students. *Research in Science Education, 32*, 549-566.

Marchionini, G. (1995). *Information Seeking in Electronic Environments*. Cambridge University Press, New York.

Marshall, D., Summers, M., & Woolnough, B. (1999). Students' conceptions of learning in an engineering context. *Higher Education, 38*, 291-309.

Marton, F., Dall'Alba, G. and Beaty E. (1993). Conceptions of learning. *International Journal of Educational Research, 19*, 277–299.

Marton, F., Watkins, D. and Tang, C. (1997). Discontinuities and continuities in the experience of learning: an interview study of high-school students in Hong Kong. *Learning and Instruction,* 7, 21–48.

Matthews, M. R. (2002). Constructivism and science education: A further appraisal. *Journal of Science Education and Technology, 11*, 121-134.

Mistler-Jackson, M., & Songer NB (2000). Student motivation and Internet technology: Are students empowered to learn science? *Journal of Research in Science Teaching, 37*, 459-479.

Muis, K. R. (2004). Personal epistemology and mathematics: A critical review and synthesis of research. *Review of Educational Research, 74*, 317-377.

National Research Council. (1996). *National science education standards*. Washington, D.C: National Academy Press.

Ng, W., & Gunstone, R. (2002). Students' perceptions of the effectiveness of the World Wide Web as a research and teaching tool in science learning. *Research in Science Education, 32*,489-510.

Oliver, K., & Hannafin, M. J. (2000). Student management of web-based hypermedia resources during open-ended problem solving. *Journal of Educational Research, 94*, 75-92.

Paulsen, M. B., & Wells, C. T. (1998). Domain differences in the epistemological beliefs of college students. *Research in Higher Education, 39,* 365-384.

Perry, W. G. (1970). *Forms of intellectual and ethical development in the college years.* New York: Holt, Rinehart & Winston.

Pomeroy, D. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary science teachers, and elementary science teachers. *Science Education, 77*, 261-278.

Rada, R., & Murphy, C. (1992). Searching versus browsing in hypertext. *Hypermedia, 4*, 1-30.

Recker, M. M., Dorward, J., & Nelson, L. M. (2004). Discovery and use of online learning resources: Case study findings. *Educational Technology & Society, 7,* 93-104.

Rivet, A. E., & Krajcik, J. S. (2004). Achieving standards in urban systemic reform: An example of a sixth grade project-based science curriculum. *Journal Research in Science Teaching, 41,* 669-692.

Rouet, J. F. (2003). What was I looking for? The influence of task specificity and prior knowledge on students' search strategies in hypertext. *Interacting with Computers, 15*, 409-428.

Ruthven, K., Hennessy, S., and Deaney, R. (2005). Incorporating Internet resources into classroom practice: pedagogical perspectives and strategies of secondary-school subject teachers. *Computers & Education, 44*, 1-34.

Schacter, J., Chung, G. K. W. K., & Dorr, A. (1998). Children's Internet searching on complex problems: Performance and process analyses. *Journal of the American Society for Information Science, 49,* 840-850.

Schommer, M. (1993). Comparisons of beliefs about the nature of knowledge and learning among postsecondary students. *Research in Higher Education, 34*, 355-370.

Schommer, M., & Walker, K. (1995). Are epistemological beliefs similar across domains? *Journal of Educational Psychology, 87*, 424-432.

Skinner, N. C., and Preece, P. F. W. (2003). The use of information and communications technology to support the teaching of science in primary schools. *International Journal of Science Education, 25,* 205-219.

Solomon, J. (1987). Social influences on the construction of pupils' understanding of science. *Studies in Science Education, 14,* 63-82.

Songer, N. B., & Linn, M. C. (1991). How do students' views of science influence knowledge integration? *Journal of Research in Science Teaching, 28,* 761-784.

Tabatabai, D., & Shore, B. M. (2005). How experts and novices search the Web. *Library & Information Science, 27*, 222-248

Tsai, C.- C. (1998a). Science learning and constructivism. *Curriculum and Teaching, 13*, 31-52.

Tsai, C.-C. (1998b). An analysis of Taiwanese eighth graders' science achievement, scientific epistemological beliefs and cognitive structure outcomes after learning basic atomic theory. *International Journal of Science Education, 20,* 413-425.

Tsai, C.-C. (1998c). An analysis of scientific epistemological beliefs and learning orientations of Taiwanese eighth graders. *Science Education, 82*, 473-489.

Tsai, C.-C. (2000). The effects of STS-oriented instruction on female tenth graders' cognitive structure outcomes and the role of student scientific epistemological beliefs. *International Journal of Science Education, 22,* 1099-1115.

Tsai, C. C. (2001a). The interpretation construction design model for teaching science and its applications to Internet-based instruction in Taiwan. *International Journal of*

Education Development, 21, 401-415.

Tsai, C. C. (2001b). A review and discussion of epistemological commitments, metacognition, and critical thinking with suggestions on their enhancement in Internet-assisted chemistry classrooms. *Journal of Chemical Education, 78*, 970-974.

Tsai, C. C. (2004a). Beyond cognitive and metacognitive tools: the use of the Internet as an 'epistemological' tool for instruction. *British Journal of Educational Technology, 35*, 525-536.

Tsai, C. C. (2004b). Information commitments in Web-based learning environment. *Innovations in Education and Teaching International, 41*, 105-112.

Tsai, C.- C. (2004c). Conceptions of learning science among high school students in Taiwan: a phenomenographic analysis. *International Journal of Science Education, 26*, 1733-1750.

Tsai, C. C., & Chuang, S. C. (2005). The correlation betweeen epistemological beliefs and preferences toward Internet-based learning environments. *British Journal of Educational Technology, 36*, 97-100.

Tsai, C.-C., & Huang, C.-M. (2002). Exploring students' cognitive structures in learning science: A review of relevant methods. *Journal of Biological Education, 36*, 163-169.

Tsai, C.-C., & Lin, C.-C. (2004). Taiwanese adolescents' perceptions and attitudes regarding the Internet: Exploring gender differences. *Adolescence, 39,* 725-734.

Tsai, C.-C., Lin, S.S.J., & Yuan, S.-M. (2000). Taiwanese high school science students' views of using a www-based concept map testing system. *International Journal of Instructional Media, 27,* 363-368.

Tsai, C.-C., Lin, S.S.J., & Yuan, S.-M. (2001). Students' use of web-based concept map testing and strategies for learning. *Journal of Computer Assisted Learning,* *17*, 72-84.

Tsai, C.-C., & Liu, S.-Y. (2005). Developing a multi-dimensional instrument for assessing students' epistemological views toward science. *International Journal of Science Education, 27,* 1621-1638.

Tsai, M. J., & Tsai, C. -C. (2003). Information searching strategies in web-based science learning: The role of Internet self-efficacy. *Innovations in Education and Teaching International, 40*, 43-50.

von Glasersfeld, E. (1989). Cgnition, construction of knowledge, and teaching. *Synthese*, *80*, 121-140.

von Glasersfeld, E. (1993). Questions and answers about radical constructivism. In K. Tobin (ed.), *The Practice of Constructivism in Science Education*, (pp. 39-50). Hillsdale, New Jersey: LEA.

Volman, M., & van Eck, E. (2001). Gender equity and information technology in education: the second decade. *Review of Educational Research, 71*, 613-634.

Voorbij, H. J. (1999). Searching scientific information on the Internet: A Dutch academic user survey. *Journal of the American Society for Information Science, 50*, 598-615.

Wanderse, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (ed.), *Handbook of research on science teaching and learning*. NY: Macmillan.

Wen, M. C. L., Tsai, C. -C., Lin, H. M., & Chuang, S. C. (2004). Cognitive-metacognitive and content-technical aspects of constructivist Internet-based learning environments: a LISREL analysis. *Computers & Education, 43*, 237-248.

Whitmire, E. (2003). Epistemological beliefs and the information-seeking behavior of undergraduates. *Library & Information Science Research, 25*, 127-142.

Whitmire, E. (2004). The relationship between undergraduates' epistemological beliefs, reflective judgment, and their information-seeking behavior. *Information Processing and Management, 40,* 97-111.

Windschitl, M., & Andre, T. (1998). Using computer simulations to enhance conceptual change: The roles of constructivist instruction and student epistemological beliefs. Journal of Research in Science Teaching, 35, 145-160.

Wu, Y. -T., & Tsai, C. -C. (2005). The information commitments: evaluative standards and information searching strategies in web-based learning environments. *Journal of Computer Assisted Learning, 21,* 374-385.

Appendixes

Appendix A: Participants' navigation flow maps in a pilot study

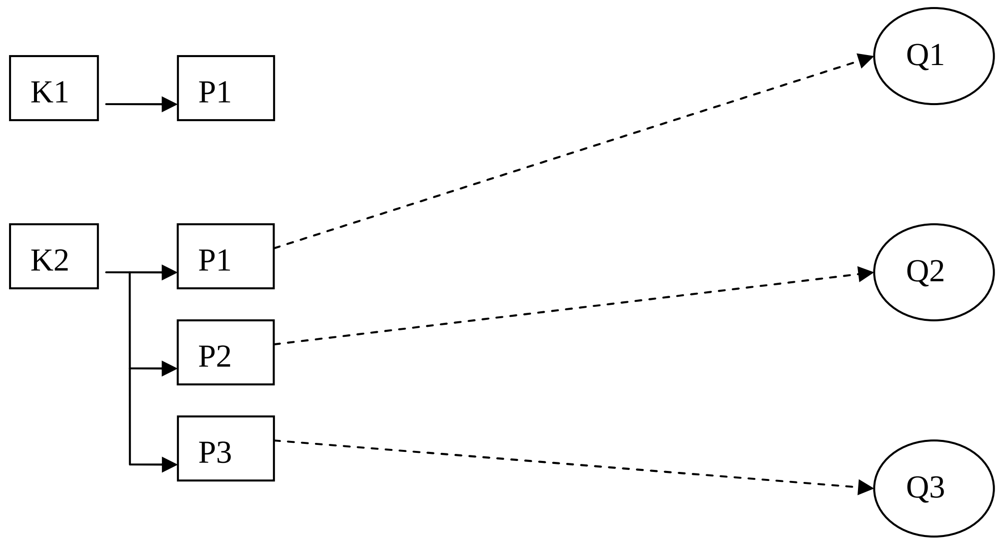


Figure 1. Navigation flow map of Participant A in the science task

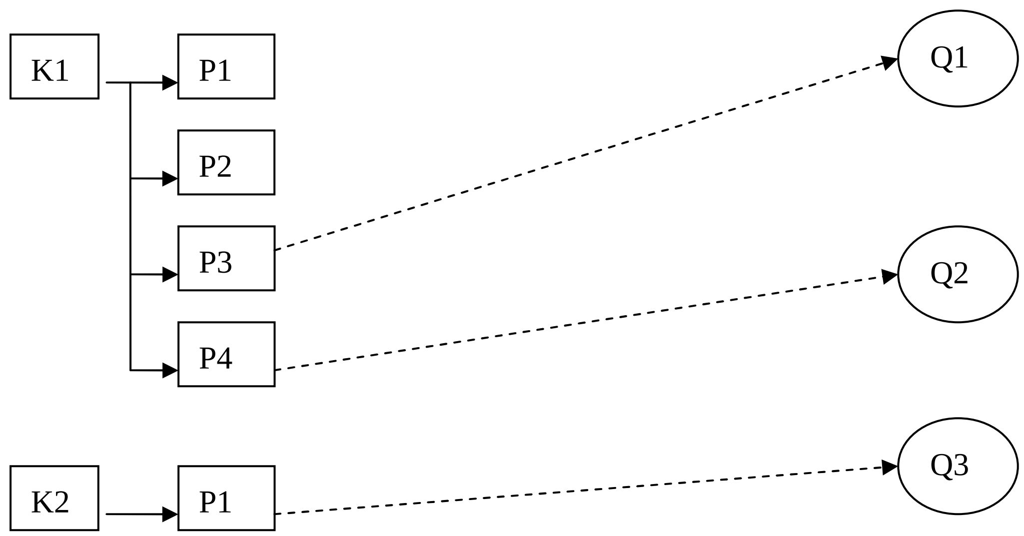


Figure 2. Navigation flow map of Participant A in the social task

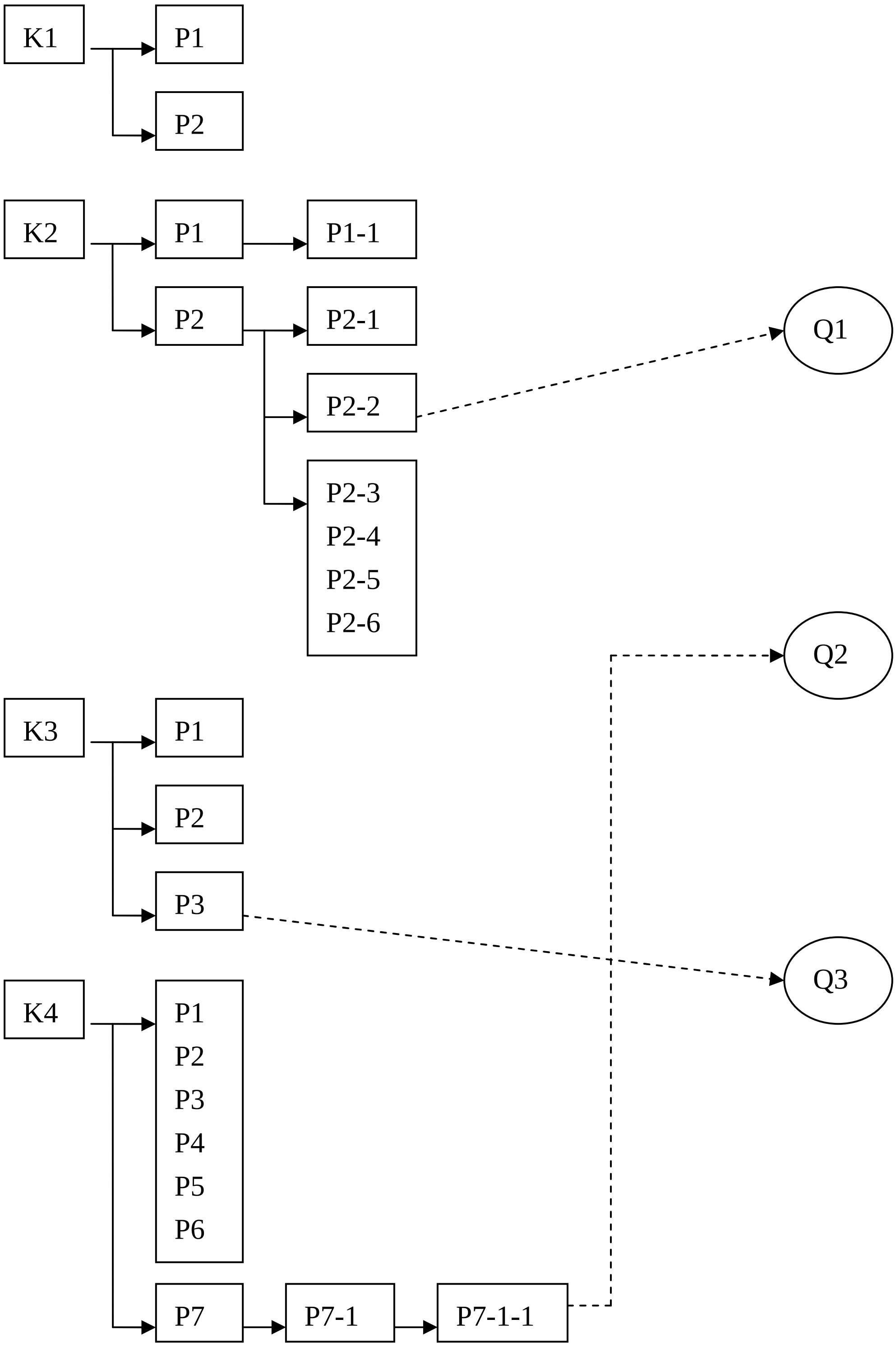


Figure 3. Navigation flow map of Participant B in the science task

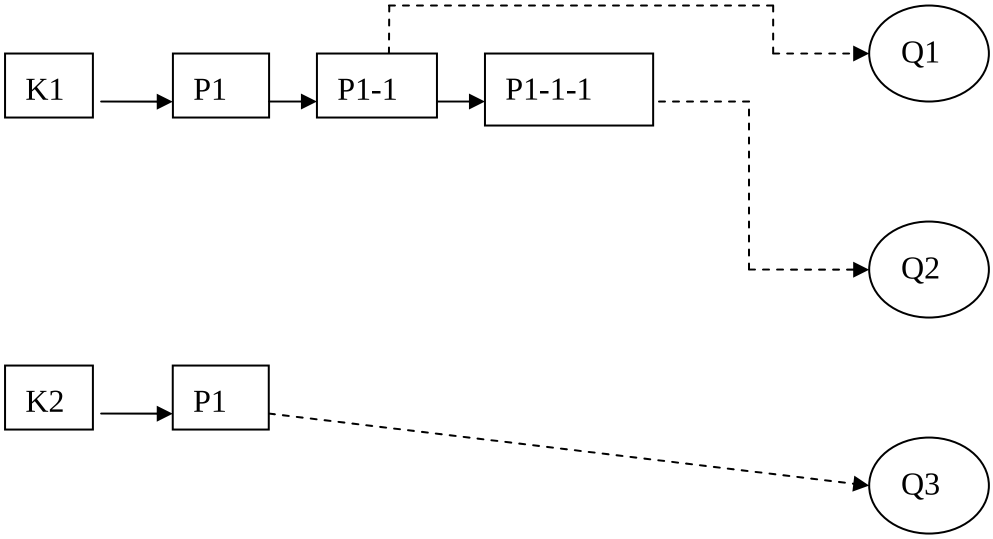


Figure 4. Navigation flow map of Participant B in the social task

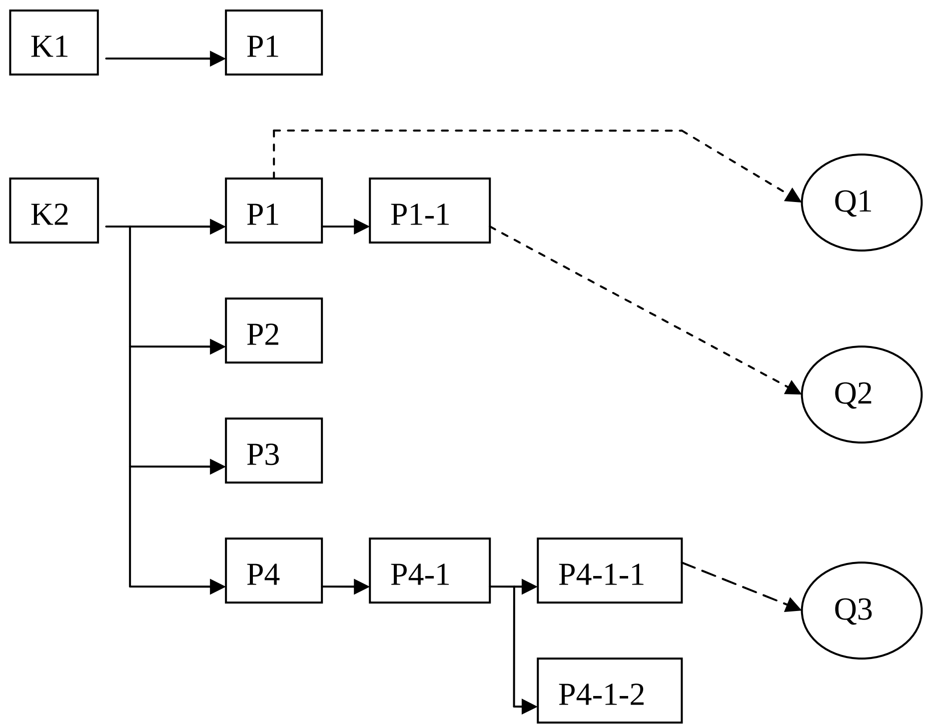


Figure 5. Navigation flow map of Participant C in the science task

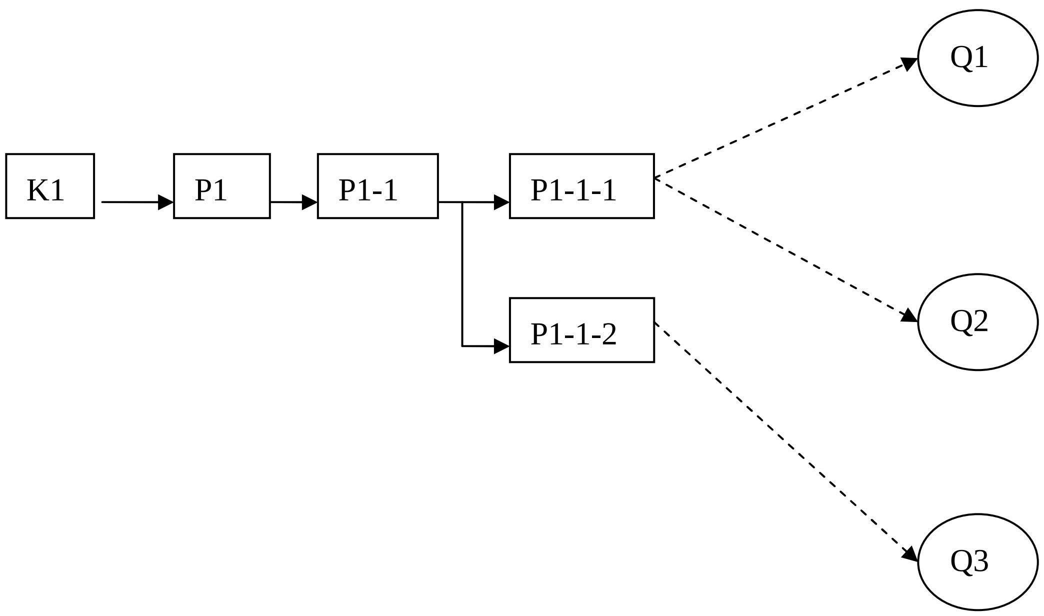


Figure 6. Navigation flow map of Participant C in the social task

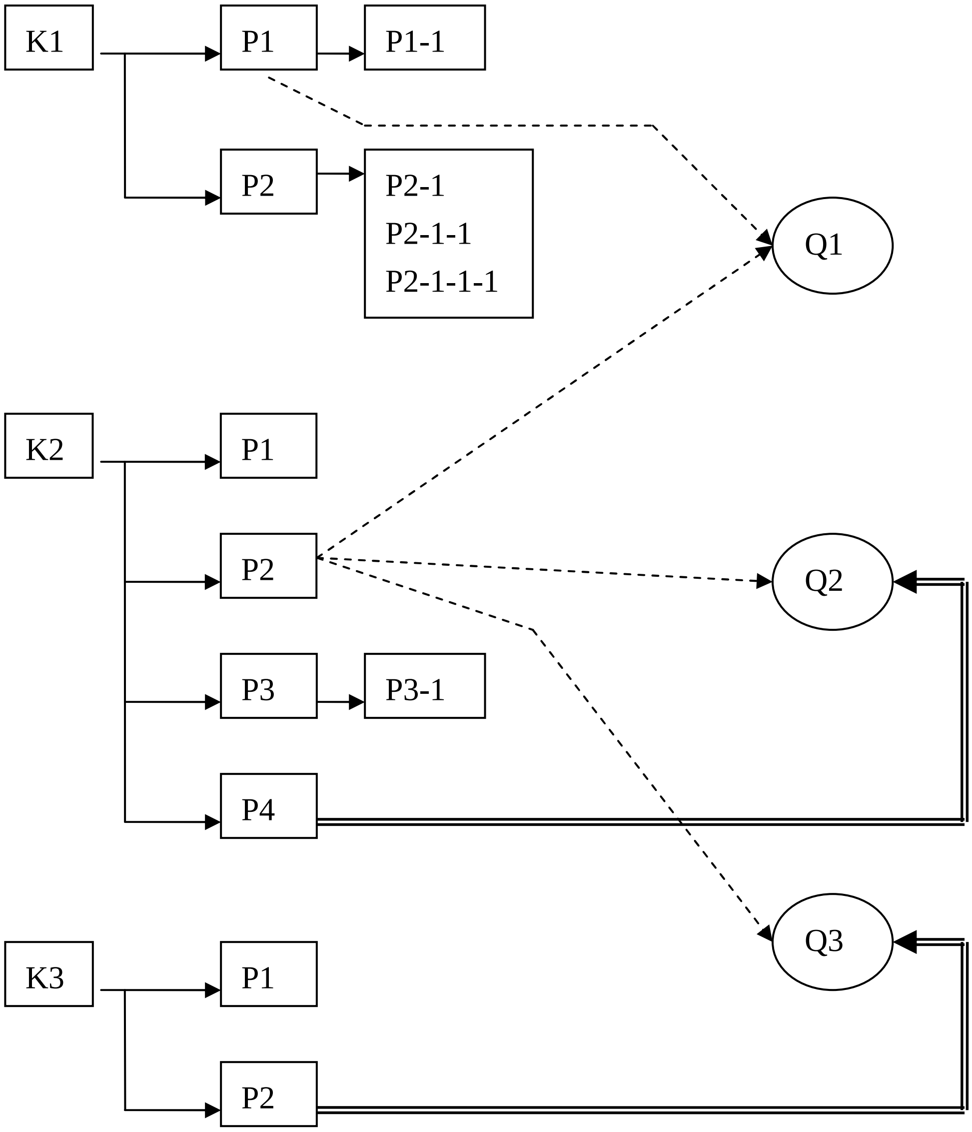


Figure 7. Navigation flow map of Participant D in the science task

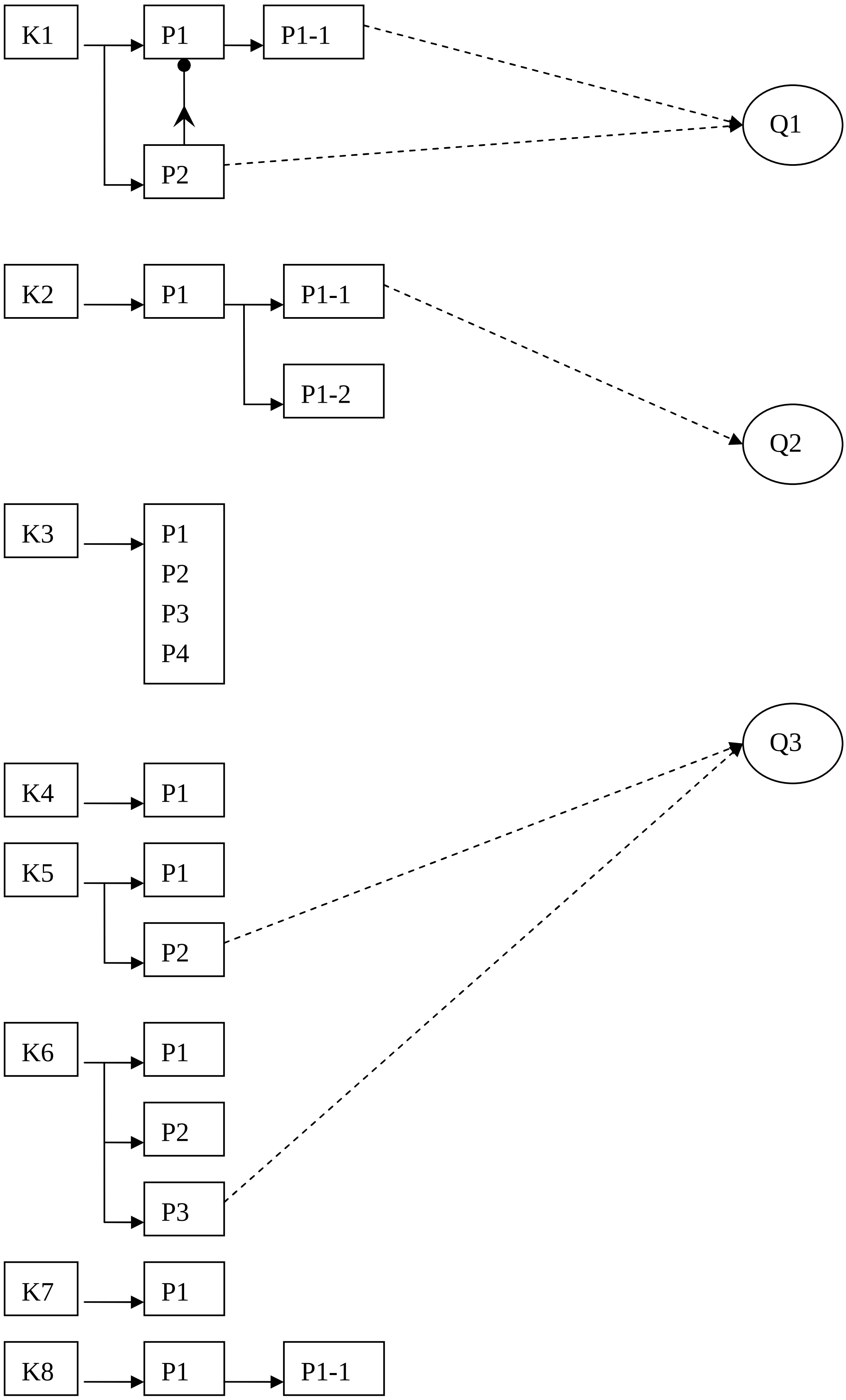


Figure 8. Navigation flow map of Participant D in the social task

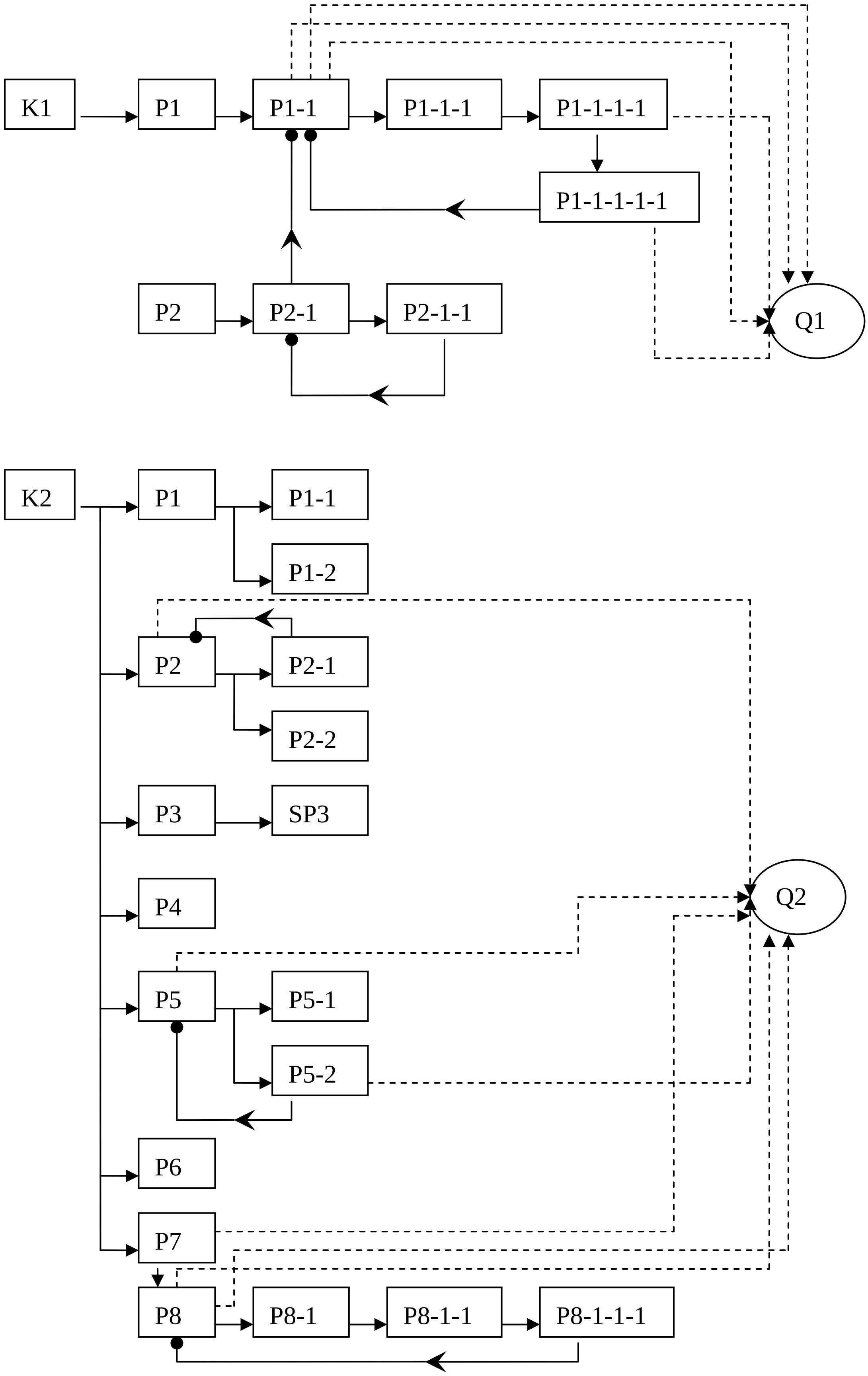
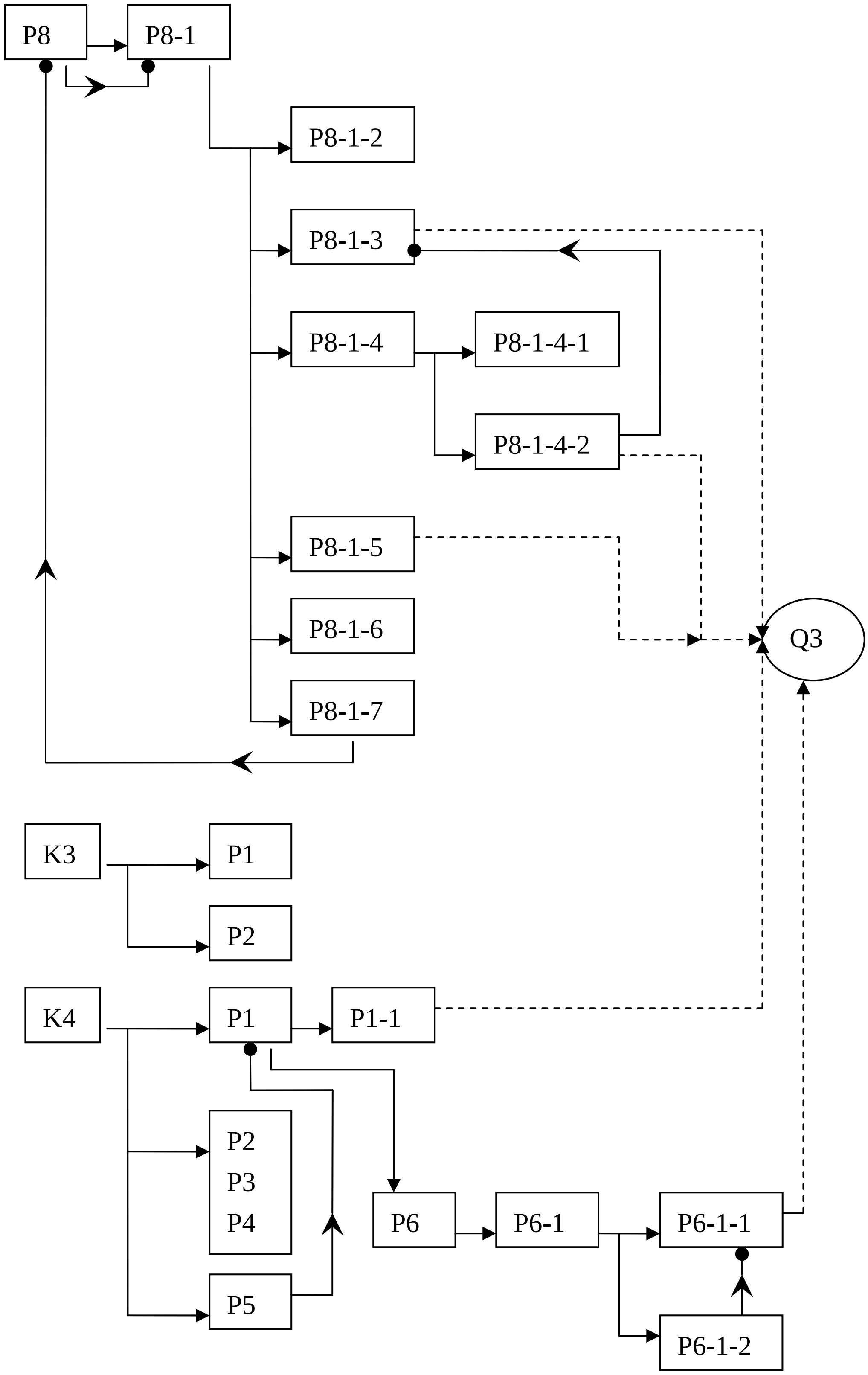


Figure 9. Navigation flow map of Participant E in the science task

Figure 9. (Continued)



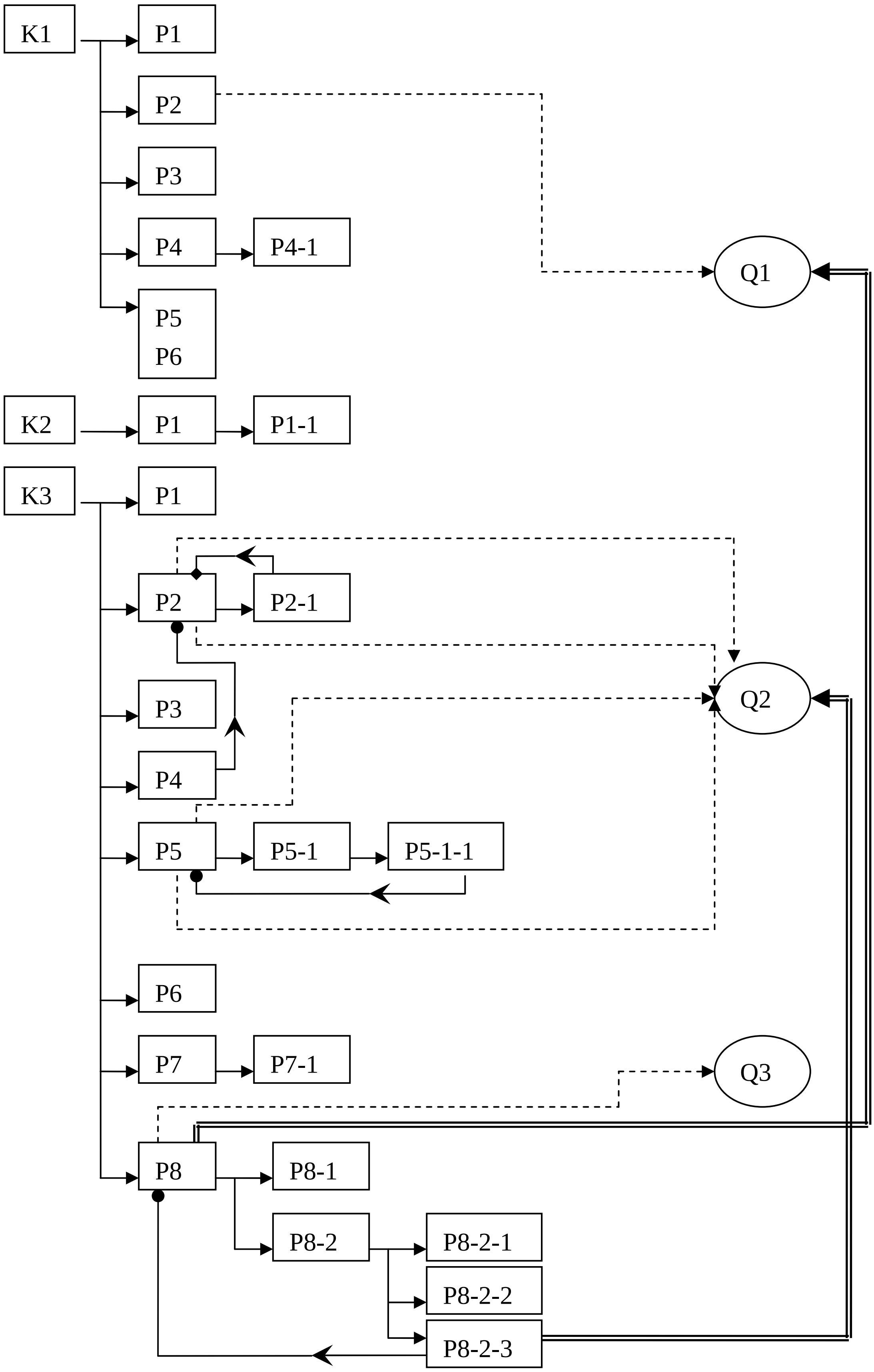


Figure 10. Navigation flow map of Participant E in the social task

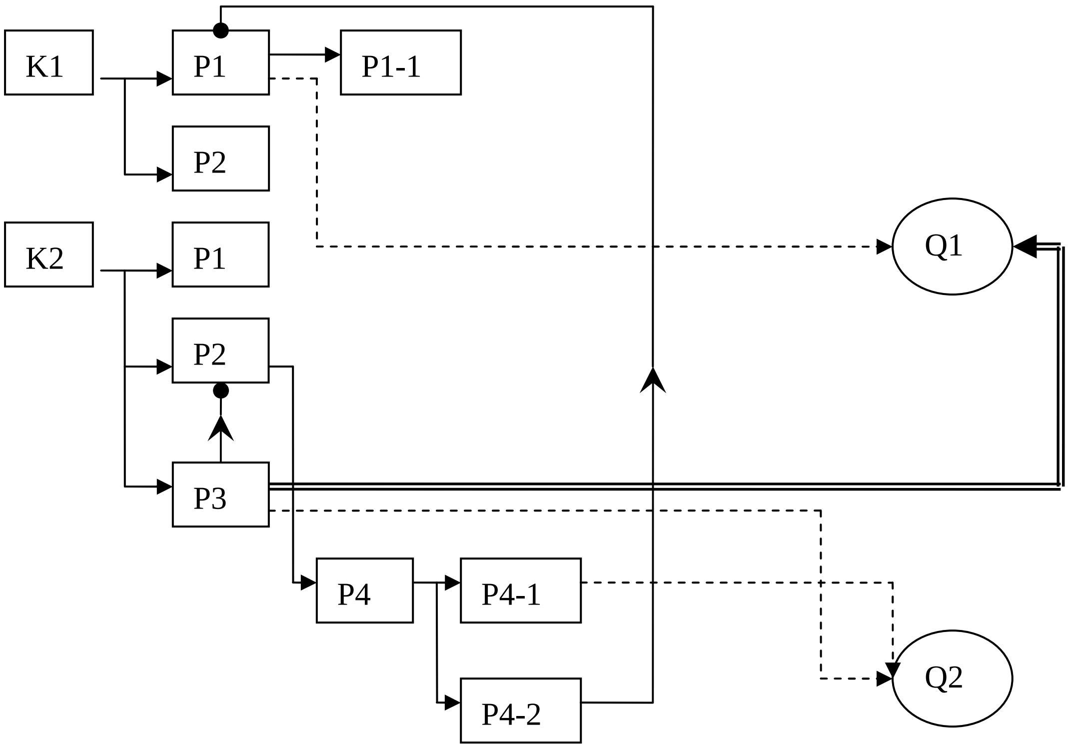


Figure 11. Navigation flow map of Participant F in the science task

Figure 11. (Continued)

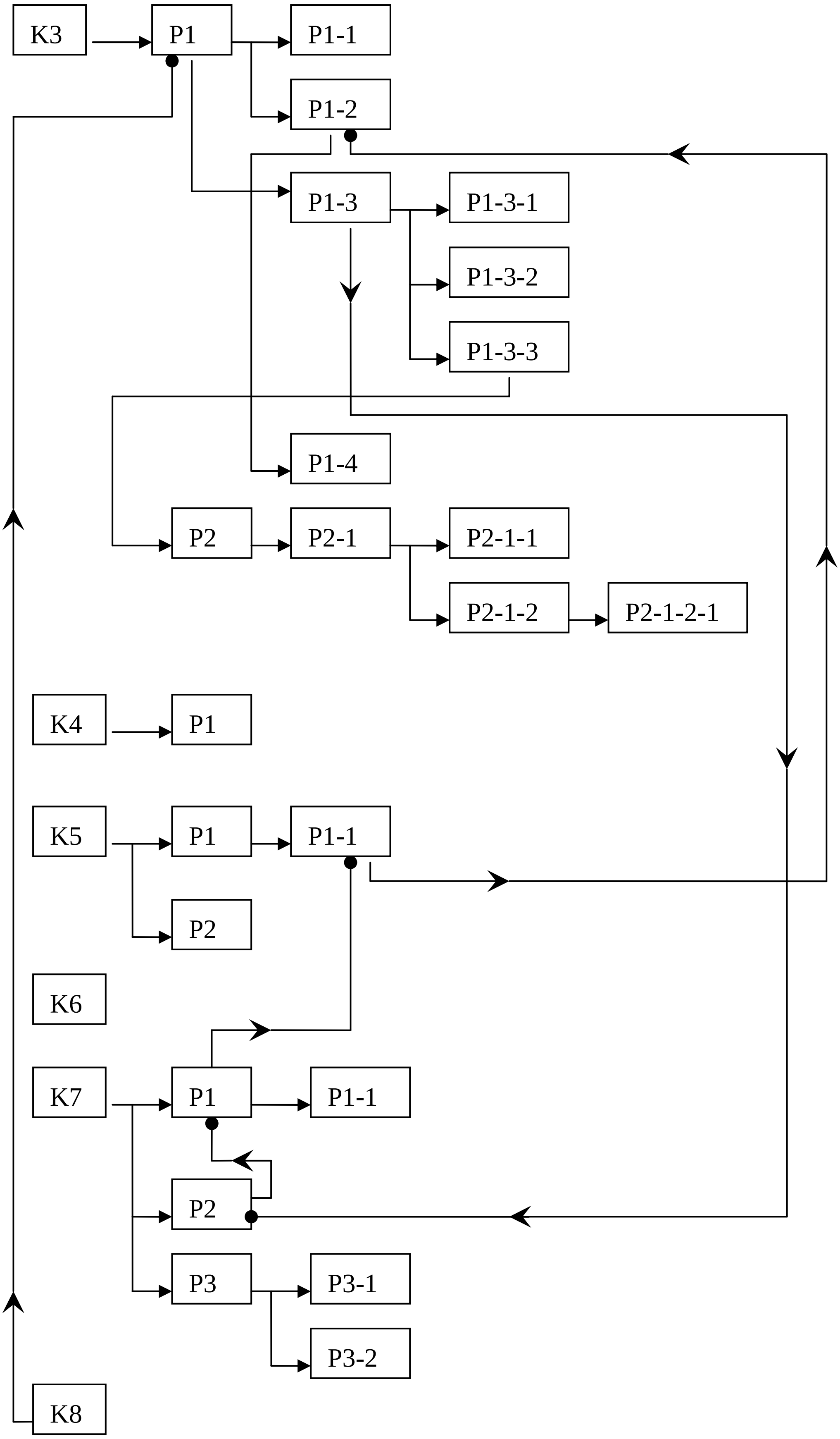
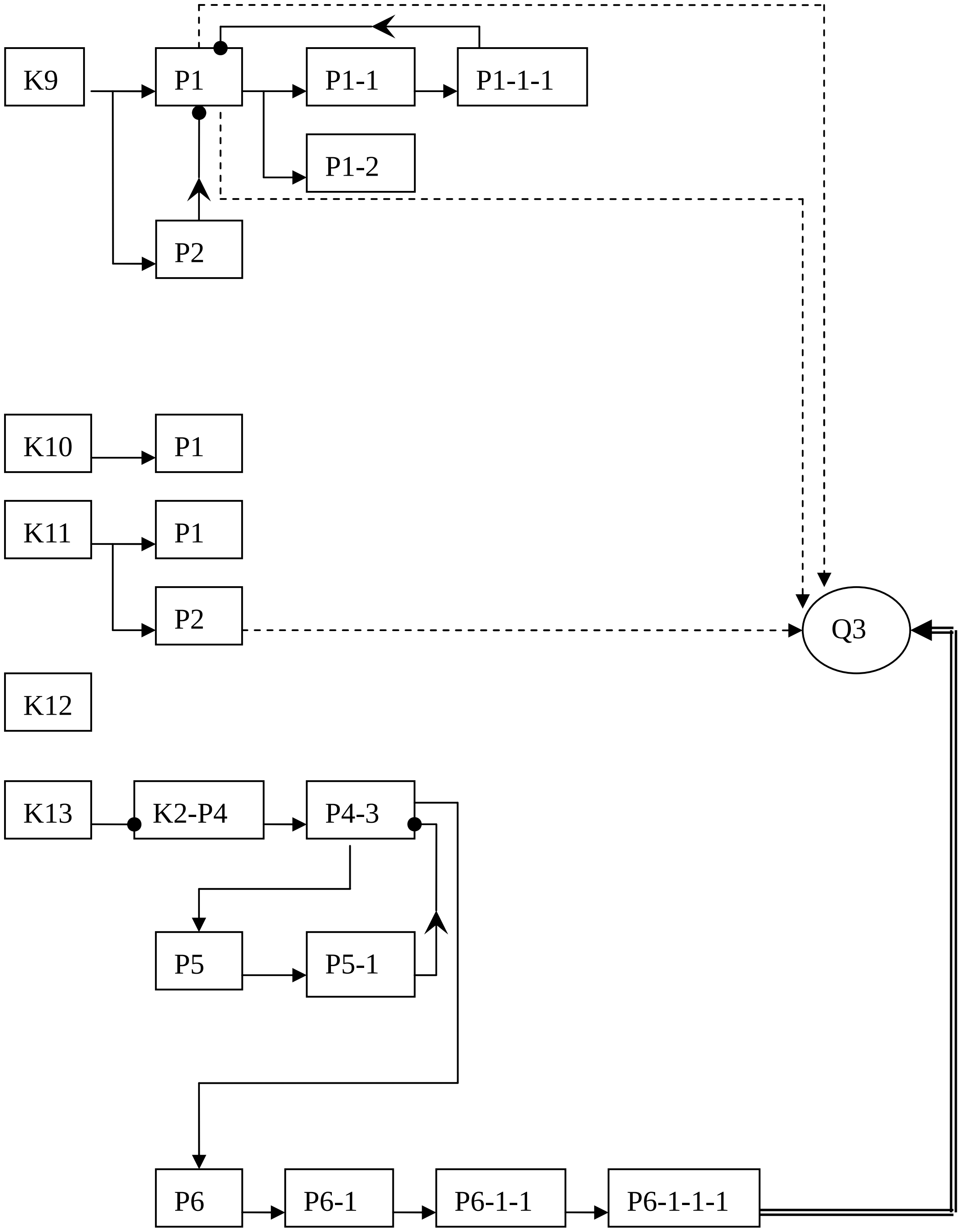


Figure 11. (Continued)



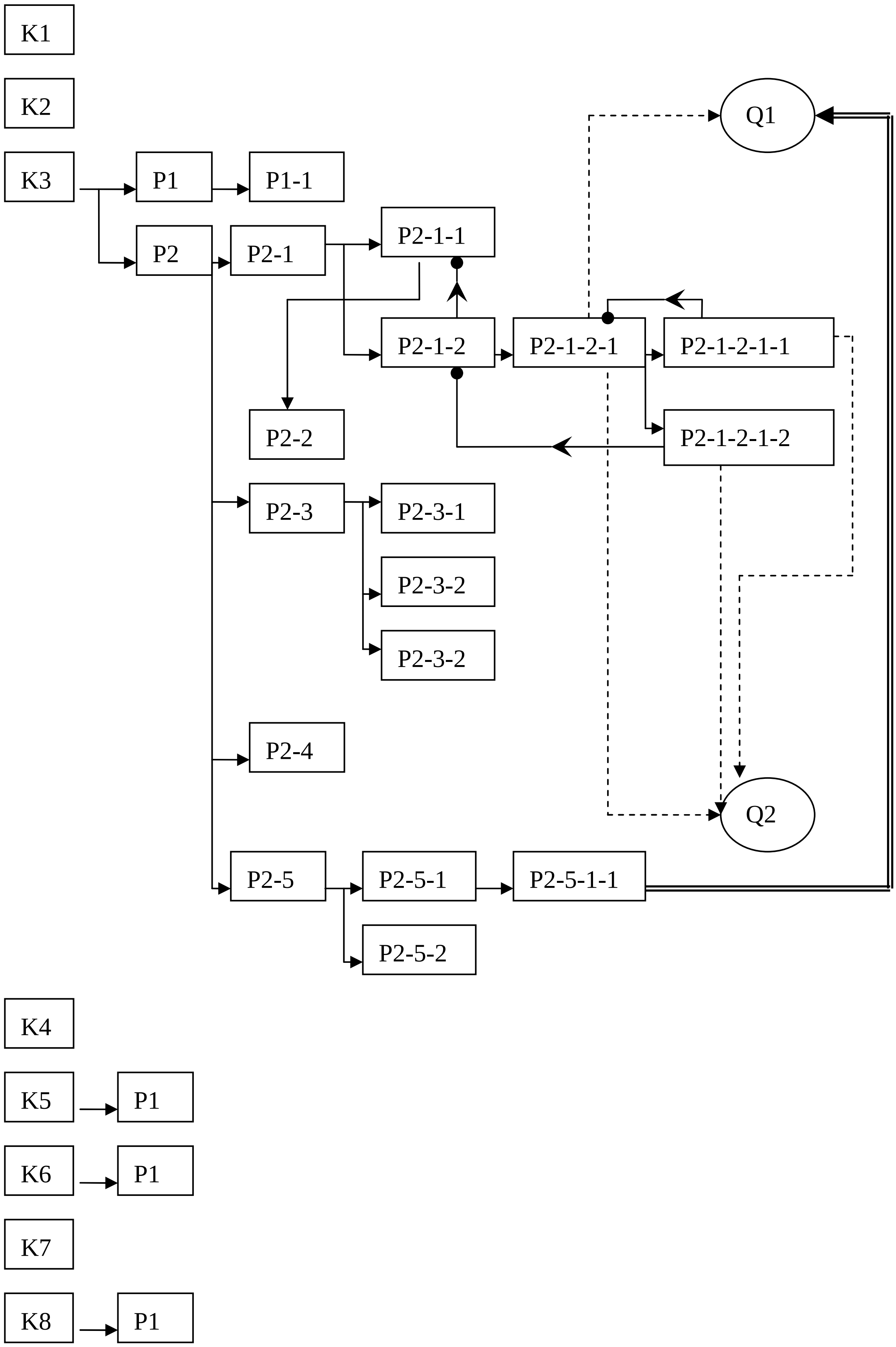
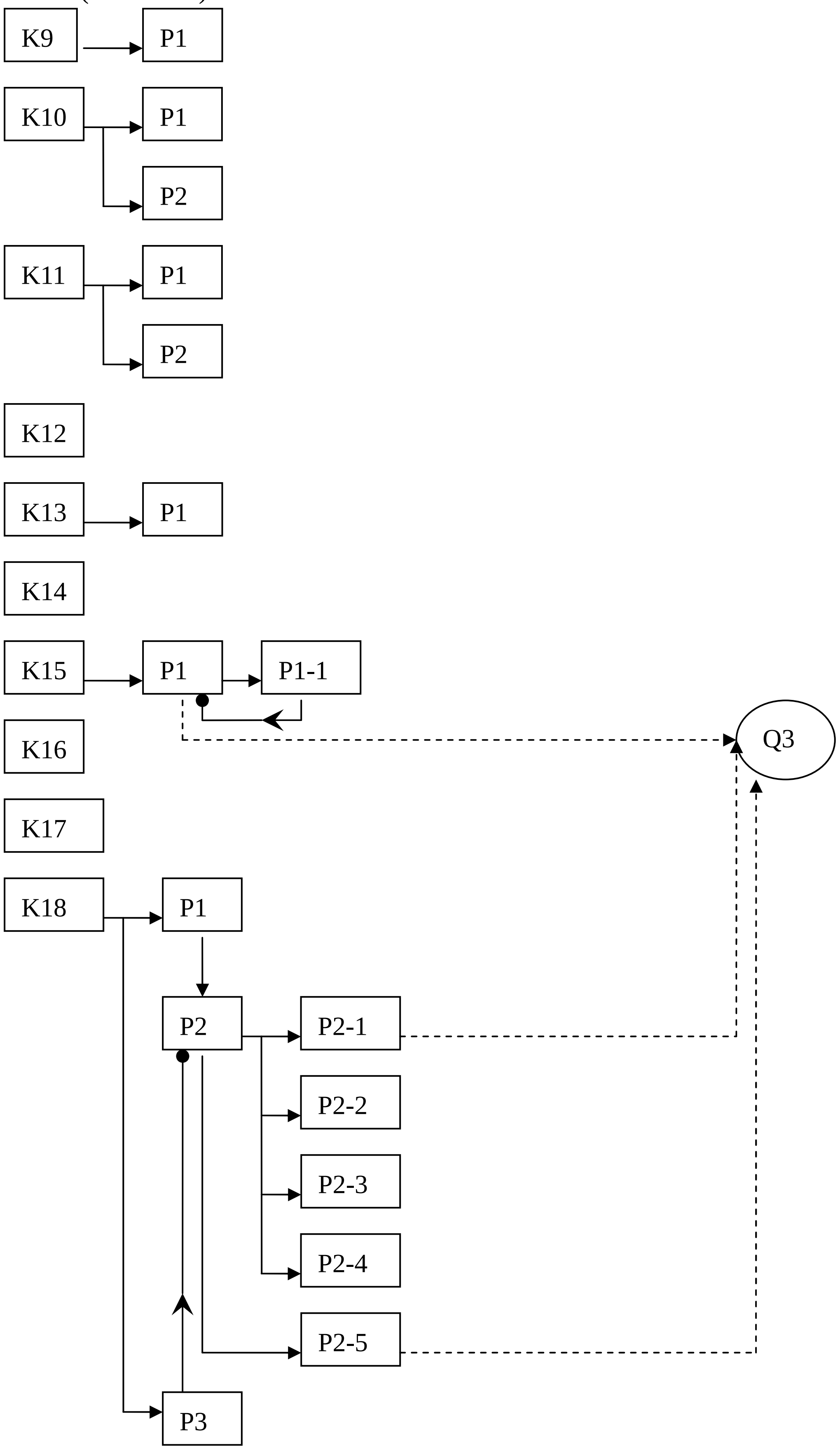


Figure 12. Navigation flow map of Participant F in Social task

Figure 12. (Continued)



Appendixes B: Chinese-version Information Commitments Survey

網路資訊評判標準問卷

您的基本資料　性別：男　女　姓名：____________　座號：______　科系：_________　年級：_____

1. 在你的日常生活中網際網路是不可或缺的？　☐ 是　☐ 否

2. 你使用網際網路的地點通常是在….？　☐ 住所　☐ 學校　☐ 其它

3. 你平均一週使用幾個小時的網際網路？　☐ 0-4 小時　☐ 5-8 小時　☐ 9-12 小時　☐ 13-16 小時　☐ 17-20 小時　☐ 21 小時以上

本問卷是用來瞭解你對網路資訊所持有的評判標準。請用下列的指標（1，2，3，4，5，6）來代表你對以下所有陳述的意見，請你用圓圈將你所認為適當的答案圈選出來

6 = 完全同意　5 = 幾乎同意　4 = 有點同意　3 = 有點不同意　2 = 幾乎不同意　1 = 完全不同意

題目	您的同意程度					
當我在網路上看到一些我所不知道的資訊時，	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
1. 我會請教老師或是其他同學之後，再判斷這些資訊正不正確。	6	5	4	3	2	1
2. 我會從找看看書本上有沒有相關的內容，再來判斷這些資訊正不正確。	6	5	4	3	2	1
3. 我會試著多找幾個網站以驗證這些資訊正不正確。	6	5	4	3	2	1
4. 我會參考其它網友的回應來判斷網路資訊正不正確。	6	5	4	3	2	1
5. 如果這些資訊同時也出現在其它相關網頁上就可能是正確的。	6	5	4	3	2	1
6. 如果這些資訊出現在比較有名的網頁或網站，我認爲這些資訊應該是正確的。	6	5	4	3	2	1
7. 如果這些資訊出現在政府機關的網頁，我認爲這些資訊應該是正確的。	6	5	4	3	2	1
8. 如果這些資訊出現在有很多人瀏覽過的網站，我認爲這些資訊應該是正確的。	6	5	4	3	2	1
9. 如果這些資訊是出現在被專家評比爲優良的網站，我認爲這些資訊應該是正確的。	6	5	4	3	2	1
10. 我覺得由專業權威人士所提供的網路資訊應該是具有正確性的。	6	5	4	3	2	1

題目	您的同意程度					
當我在瀏覽網頁或網站上的資訊時，	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
11. 如果這些內容很符合我所要搜尋的資訊，那麼這些資訊對我而言是有用的。	6	5	4	3	2	1
12. 如果可以提供更多相關資訊的連結，那麼這些資訊對我而言是有用的。	6	5	4	3	2	1
13. 如果可以幫助我進一步搜尋相關的資訊，那麼這些資訊對我而言是有用的。	6	5	4	3	2	1
14. 如果這些資訊愈接近我要搜尋的目的，我會覺得愈有用。	6	5	4	3	2	1
15. 如果這些資訊和我所要搜索的內容相關性很高時，那麼這些資訊對我而言是有用的。	6	5	4	3	2	1
16. 如果這些資訊用動畫的方式來呈現，那麼這些資訊對我而言是有用的。	6	5	4	3	2	1
17. 如果讀取這些資訊時不需要等待太久，那麼這些資訊對我而言是有用的。	6	5	4	3	2	1
18. 如果進到網頁時不需要密碼或是註冊，那麼這個網頁的資訊對我而言是有用的。	6	5	4	3	2	1
19. 如果這個網頁或網站愈美觀，我會覺得這個網頁或網站的資訊愈有用。	6	5	4	3	2	1
20. 如果網站有提供進階搜尋的功能，我會認為這個網頁的資訊就愈有用。	6	5	4	3	2	1

題目	您的同意程度					
當我需要在網路上搜尋資訊時，	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
21. 我習慣將搜尋到的許多資訊加以歸納整理，成為自己所需要的資訊。	6	5	4	3	2	1
22. 我會利用已搜尋到的資訊做進階的搜索，以找到最符合自己需要的資訊。	6	5	4	3	2	1
23. 在搜索的過程中，我會不斷判斷那些資訊是我所需要的。	6	5	4	3	2	1
24. 我會整合來自不同網頁或網站的資訊。	6	5	4	3	2	1
25. 我會不斷提醒自己在網路上搜索的目的。	6	5	4	3	2	1
26. 我會去比較相關網站所呈現的不同資訊。	6	5	4	3	2	1
27. 我通常只利用搜索引擎找到一個最符合我需要的網站或網頁。	6	5	4	3	2	1
28. 當我找到第一個相關的網頁時，我就不會再進一步搜尋其他的網頁。	6	5	4	3	2	1
29. 我只想找到一個相關資訊最豐富的網頁就好了。	6	5	4	3	2	1
30. 我通常在搜尋引擎上只使用一組關鍵字來搜尋相關網頁。	6	5	4	3	2	1
31. 我通常只擷取一個網頁上的資訊來回答相關問題。	6	5	4	3	2	1

Appendixes C: Chinese-version Scientific Epistemological views questionnaire

科 學 觀 點 問 卷

您的基本資料　性別：男　女　姓名：____________ 座號：______　科系：_________ 年級：_____

本問卷是用來瞭解你對網路資訊所持有的評判標準。請用下列的指標（1，2，3，4，5，6）來代表你對以下所有陳述的意見，請你用圓圈將你所認為適當的答案圈選出來

6 = 完全同意　5 = 幾乎同意　4 = 有點同意　3 = 有點不同意　2 = 幾乎不同意　1 = 完全不同意

題目	您的同意程度					
	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
1.　科學家的直覺在科學發展的過程中，扮演一個重要的角色。	6	5	4	3	2	1
2.　一些現在被接受的科學知識是從人類幻想與預感而來的。	6	5	4	3	2	1
3.　科學理論發展的過程中需要科學家的想像力與創造力。	6	5	4	3	2	1
4.　創造力在科學知識發展的過程中扮演一重要的角色。	6	5	4	3	2	1
5.　科學家可能會從個人生活經驗中得到解決科學問題的靈感與想法。	6	5	4	3	2	1
6.　科學理論的形成是經由科學家探索自然現象所研究發明的結果。	6	5	4	3	2	1
7.　科學理論是早已存在於自然現象中，一種等待科學家去發現的事實。	6	5	4	3	2	1

題目	您的同意程度					
	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
8.　科學家的研究活動會受他們既有理論的影響。	6	5	4	3	2	1
9.　科學家可做完全客觀的觀察。	6	5	4	3	2	1
10．科學探索的過程中是不會受科學家既有理論的影響。	6	5	4	3	2	1
11．科學理論是科學家用來解釋與研究自然現象的依據。	6	5	4	3	2	1
12．不同理論背景的科學家會對同一種自然現象產生不同的看法。	6	5	4	3	2	1
13．科學家會選擇最適當的科學理論來解釋實驗所產生的數據及現象。	6	5	4	3	2	1
14．科學理論的創新可能會以先前理論作為研究發展的基礎。	6	5	4	3	2	1

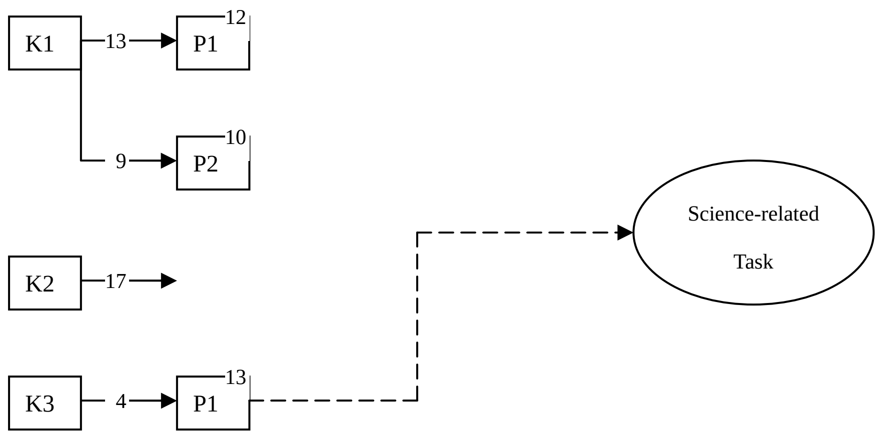
題目	您的同意程度					
	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
15. 科學知識發展的過程中經歷過概念的一再變更。	6	5	4	3	2	1
16. 現有科學知識提供對於自然現象暫時性的解釋。	6	5	4	3	2	1
17. 現在被認可的科學知識可能未來會改變或甚至被捨棄。	6	5	4	3	2	1
18. 科學理論被科學家提出並認同後就不會再改變。	6	5	4	3	2	1
19. 科學理論不會因爲年代的不同而產生變化。	6	5	4	3	2	1
20. 科學家可能會藉由質疑先前的理論而發展出新的科學理論。	6	5	4	3	2	1
21. 科學理論必須經由不斷地修正才能更合理地解釋自然現象。	6	5	4	3	2	1

題目	您的同意程度					
	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
22. 一個新的科學理論需經由科學社群的大部分科學家認可才有其效力。	6	5	4	3	2	1
23. 科學家們有一套共同認同的觀點與方式進行科學研究。	6	5	4	3	2	1
24. 科學知識是經由科學家們共同討論辯證出來的。	6	5	4	3	2	1
25. 有效的科學知識需經由相關領域科學家的認可。	6	5	4	3	2	1
26. 當代的科學家有一套共同接受的標準以評定科學研究結果的可靠性。	6	5	4	3	2	1
27. 科學家間的不斷討論辯證可形成更好的科學理論。	6	5	4	3	2	1

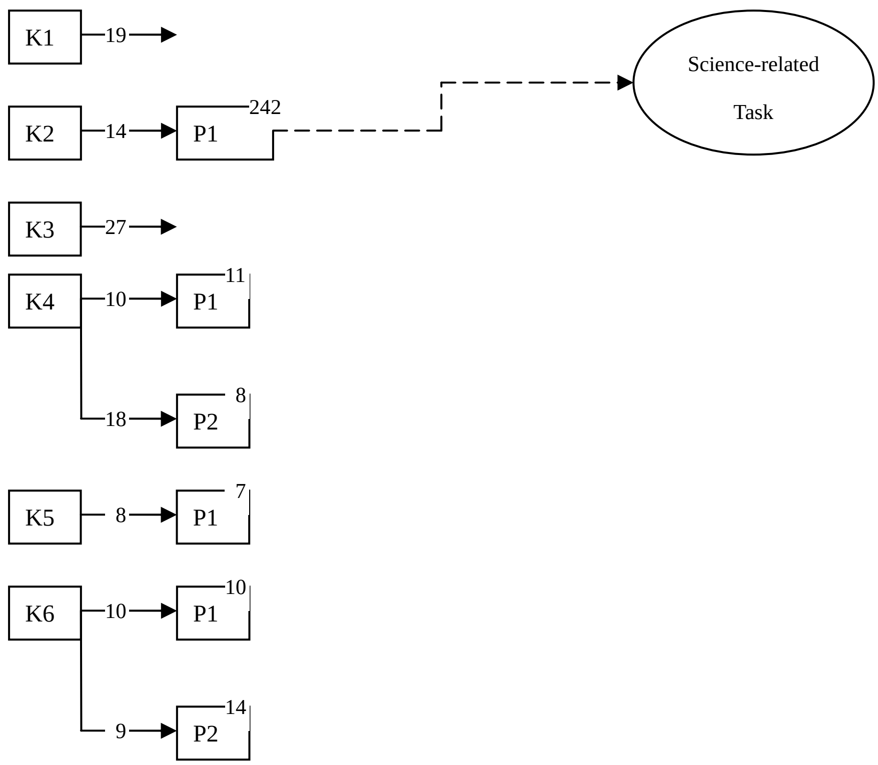
題目	您的同意程度					
	完全同意	幾乎同意	有點同意	有點不同意	幾乎不同意	完全不同意
28. 不同文化族群的人，有不同的方法或過程來獲得有效的科學知識。	6	5	4	3	2	1
29. 科學知識的發展與應用會受到不同民族文化傳統所影響。	6	5	4	3	2	1
30. 不同文化族群的人對於科學知識的重要性會持有不同的標準。	6	5	4	3	2	1
31. 不同文化背景的科學家可能會發展出不同的科學理論。	6	5	4	3	2	1
32. 因爲科學具有普遍性和客觀性，所以各個文化下的科學知識都是相同的。	6	5	4	3	2	1
33. 不同文化族群的人，有同樣的方法解釋自然現象。	6	5	4	3	2	1

Appendixes D: Navigation flow maps of six-two high school students

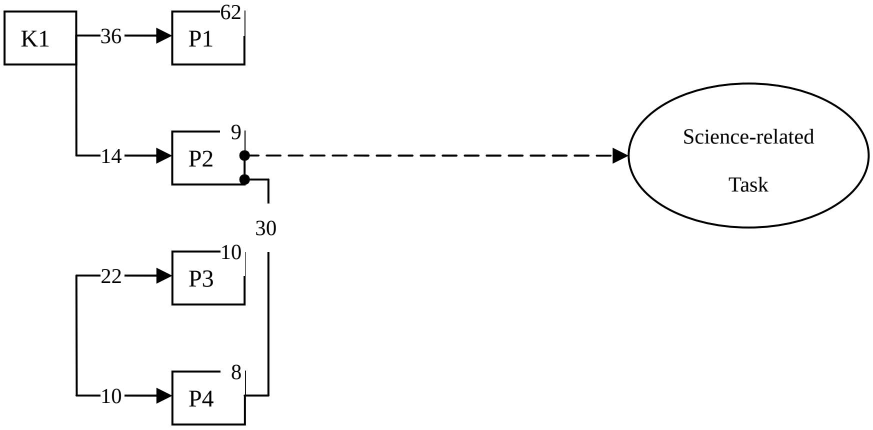
No.2



No.3

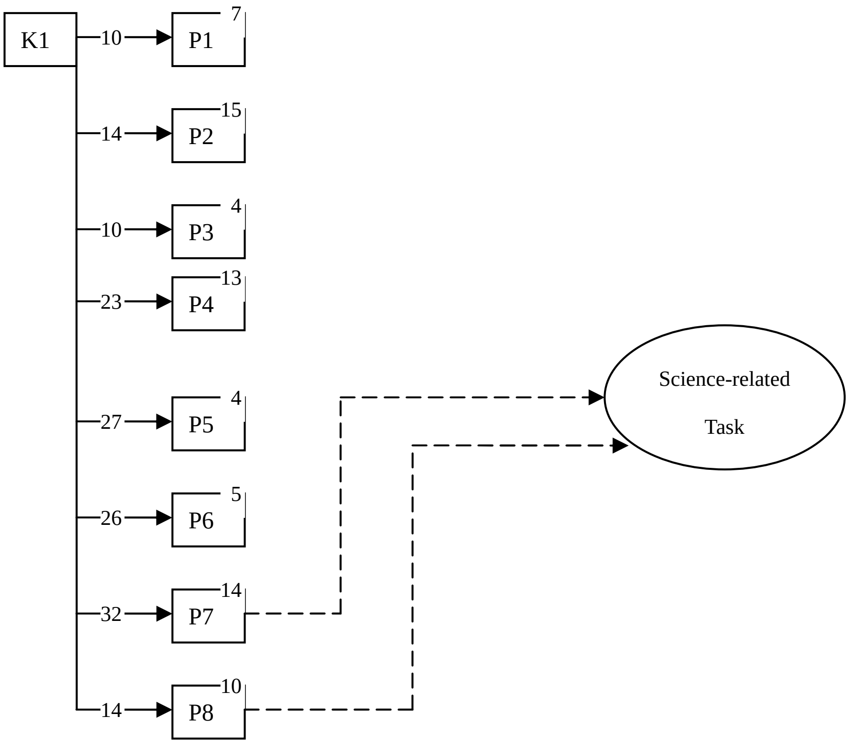


No.4



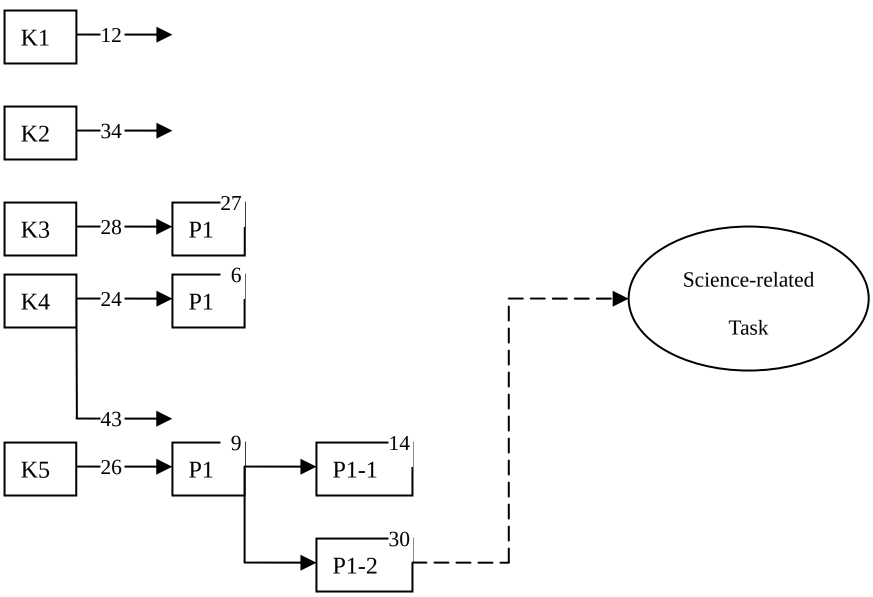
K1
36
P1
62
14
P2
9
Science-related
Task
30
22
P3
10
10
P4
8

No.5

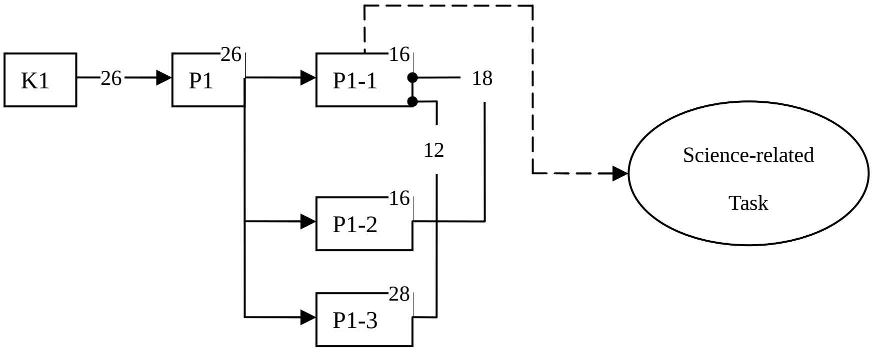


K1
10
P1
7
14
P2
15
10
P3
4
23
P4
13
27
P5
4
Science-related
Task
26
P6
5
32
P7
14
14
P8
10

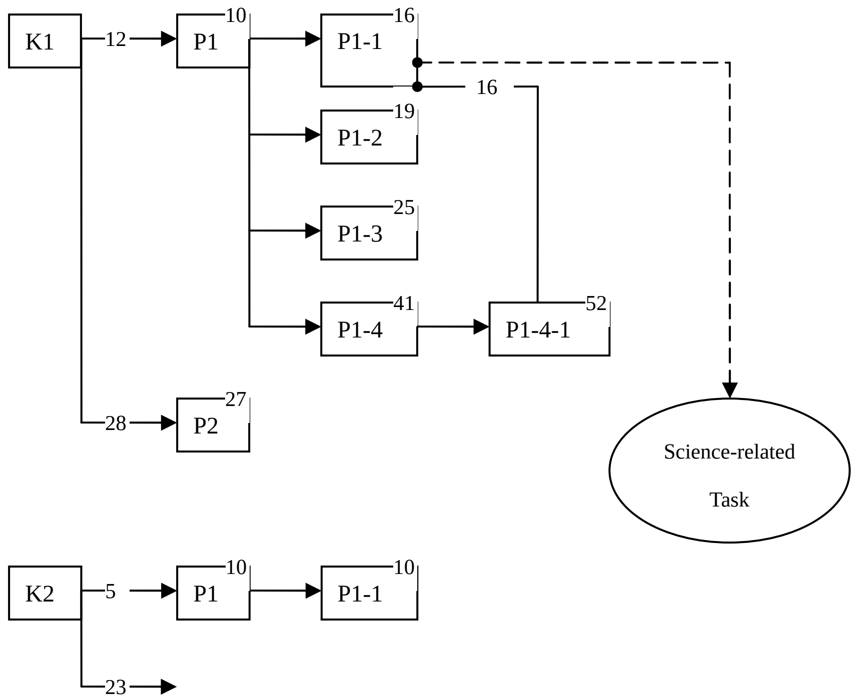
No.6


K1
12
K2
34
K3
28
P1
27
K4
24
P1
6
43
K5
26
P1
9
P1-1
14
P1-2
30
Science-related
Task

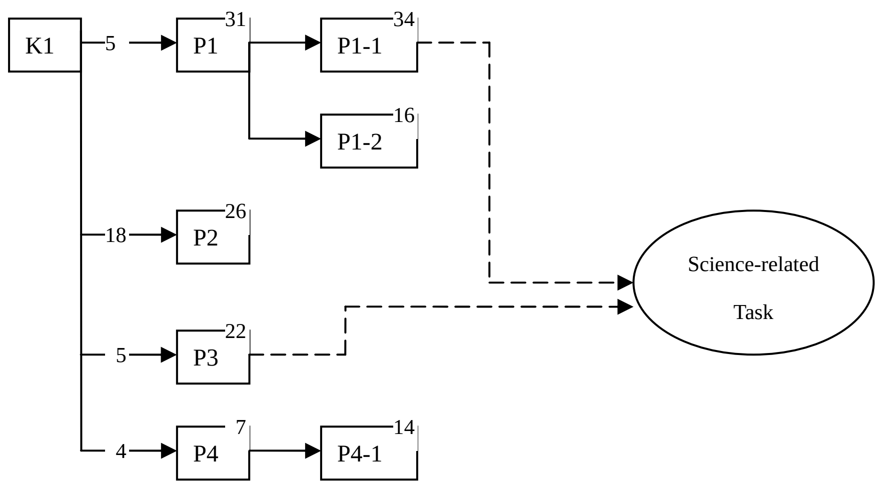
No.8


K1
26
P1
26
P1-1
16
18
12
P1-2
16
P1-3
28
Science-related
Task

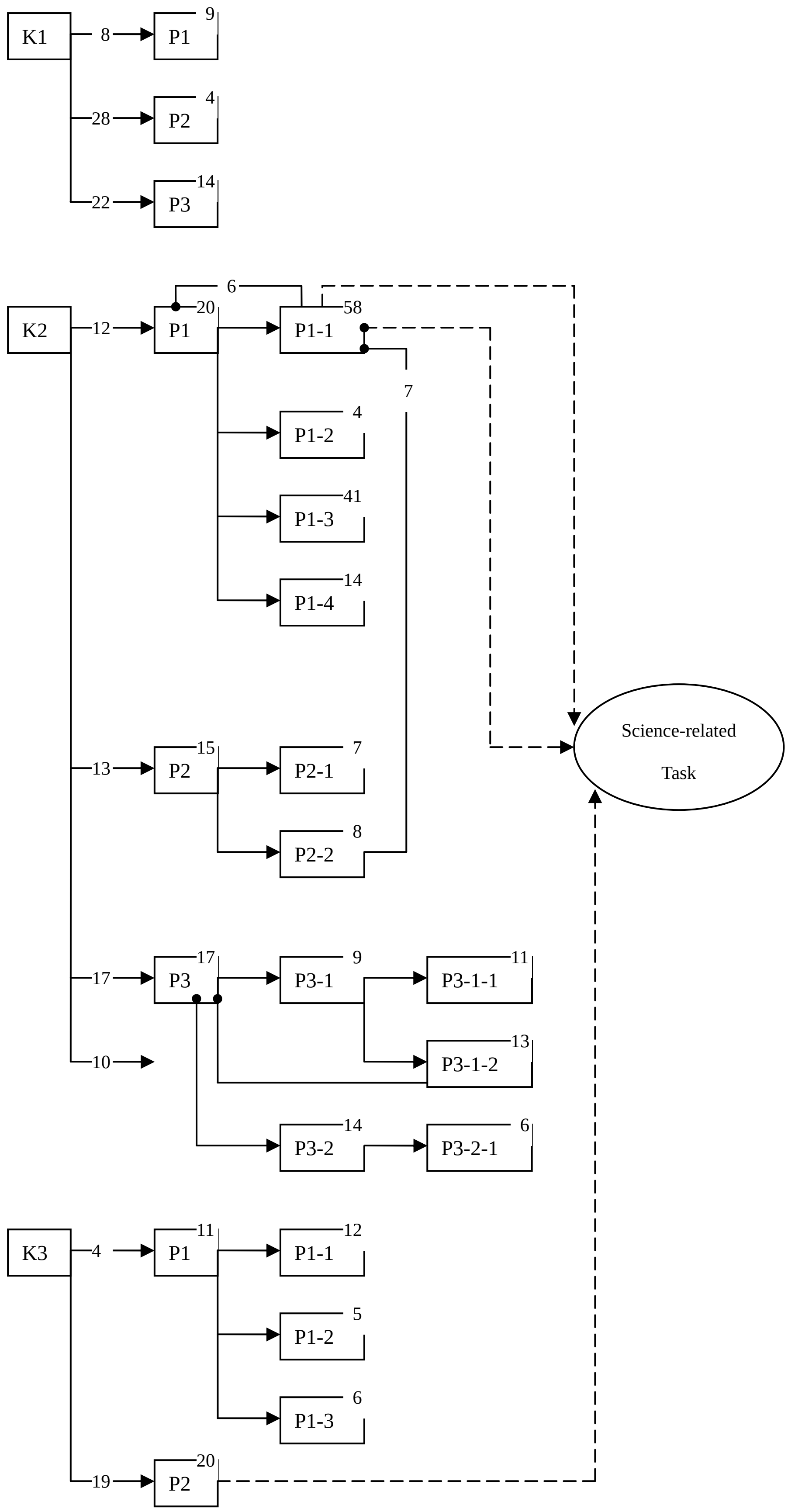
No.10


K1
12
P1
10
P1-1
16
16
P1-2
19
P1-3
25
P1-4
41
P1-4-1
52
28
P2
27
Science-related
Task
K2
5
P1
10
P1-1
10
23

No.11

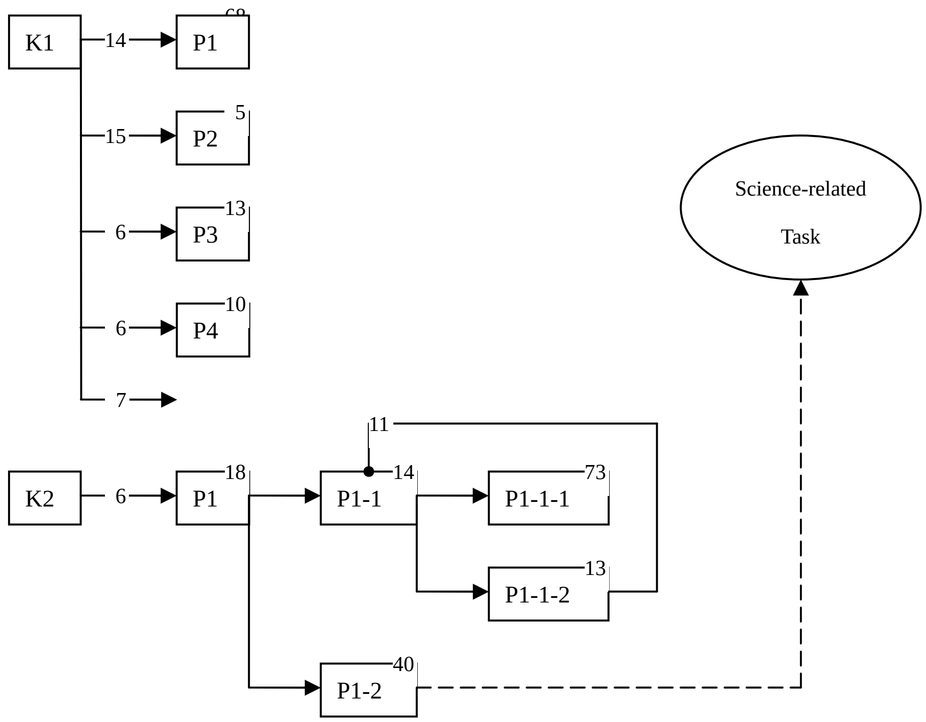

K1
5
P1
31
P1-1
34
P1-2
16
18
P2
26
5
P3
22
4
P4
7
P4-1
14
Science-related
Task

No.12



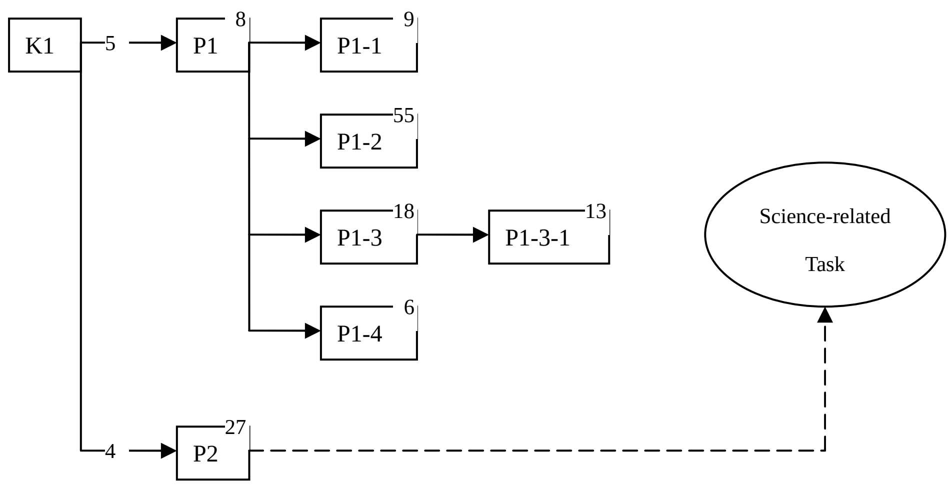
K1
8
P1
9
28
P2
4
22
P3
14
K2
12
P1
20
6
P1-1
58
7
P1-2
4
P1-3
41
P1-4
14
13
P2
15
P2-1
7
P2-2
8
17
P3
17
P3-1
9
P3-1-1
11
P3-1-2
13
10
P3-2
14
P3-2-1
6
Science-related
Task
K3
4
P1
11
P1-1
12
P1-2
5
P1-3
6
19
P2
20

No.13



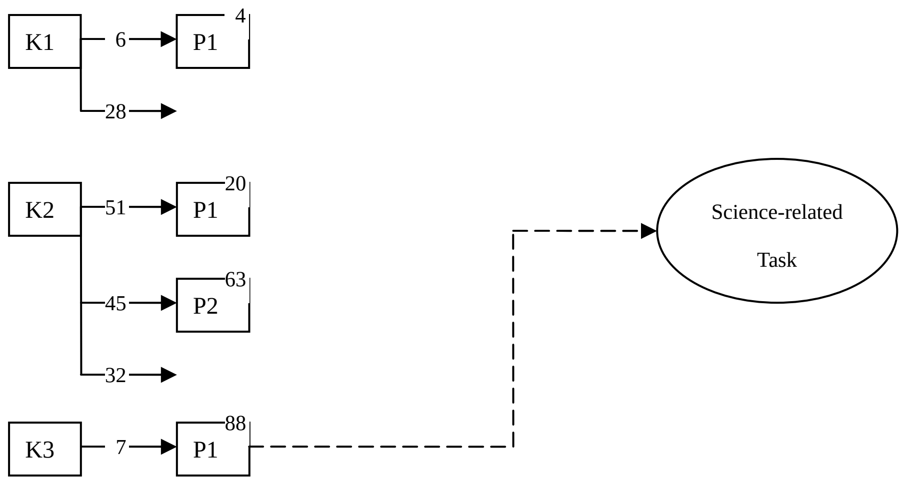
K1
14
P1
15
P2
5
6
P3
13
6
P4
10
7
K2
6
P1
18
P1-1
14
11
P1-1-1
73
P1-1-2
13
P1-2
40
Science-related
Task

No.14

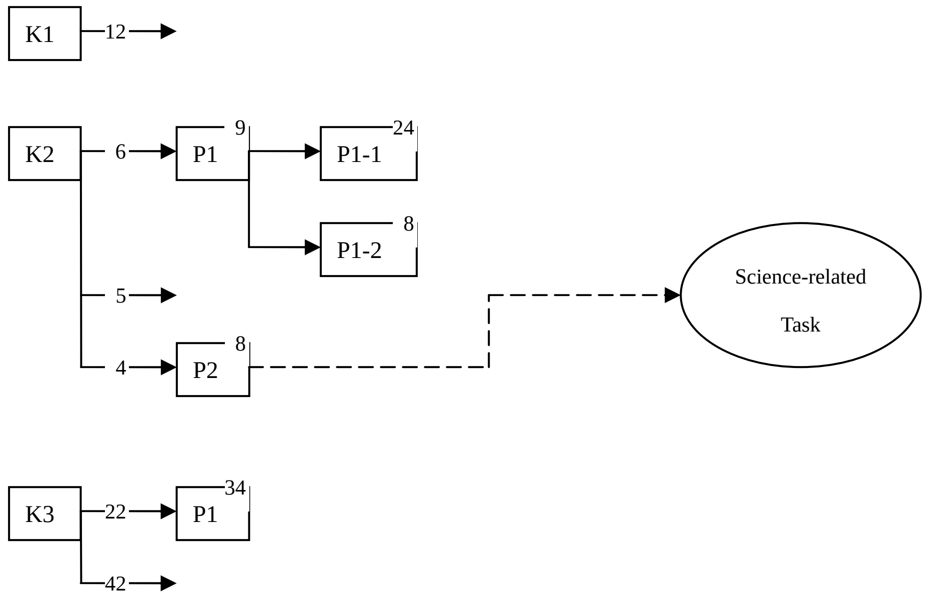


K1
5
P1
8
P1-1
9
P1-2
55
P1-3
18
P1-3-1
13
P1-4
6
4
P2
27
Science-related
Task

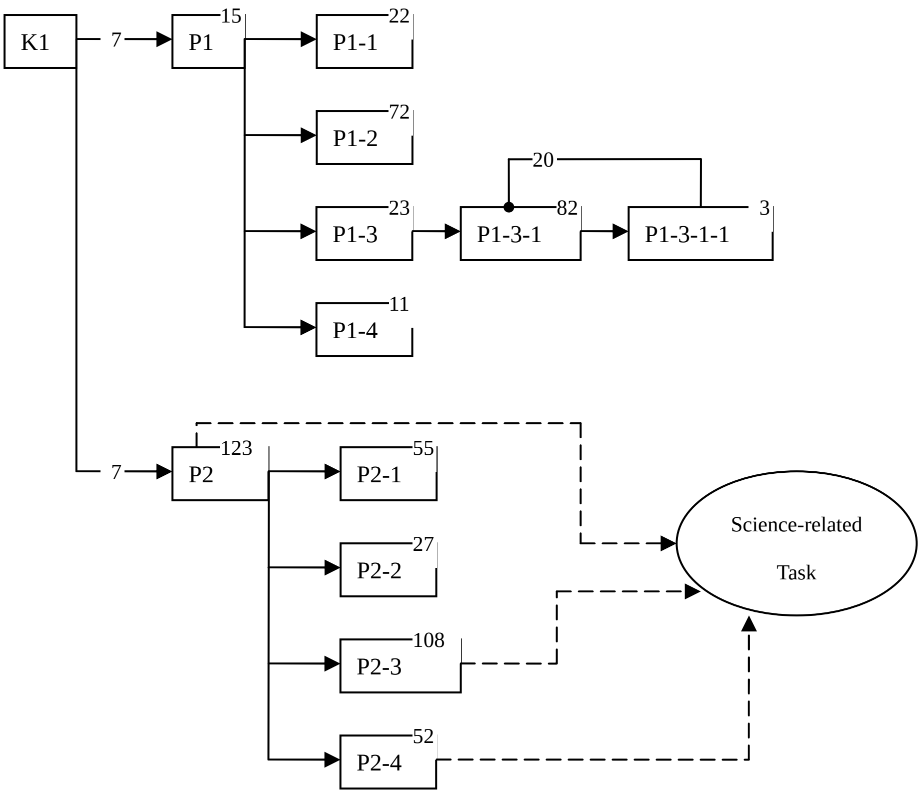
No.15


K1
6
P1
4
28
K2
51
P1
20
45
P2
63
32
K3
7
P1
88
Science-related
Task

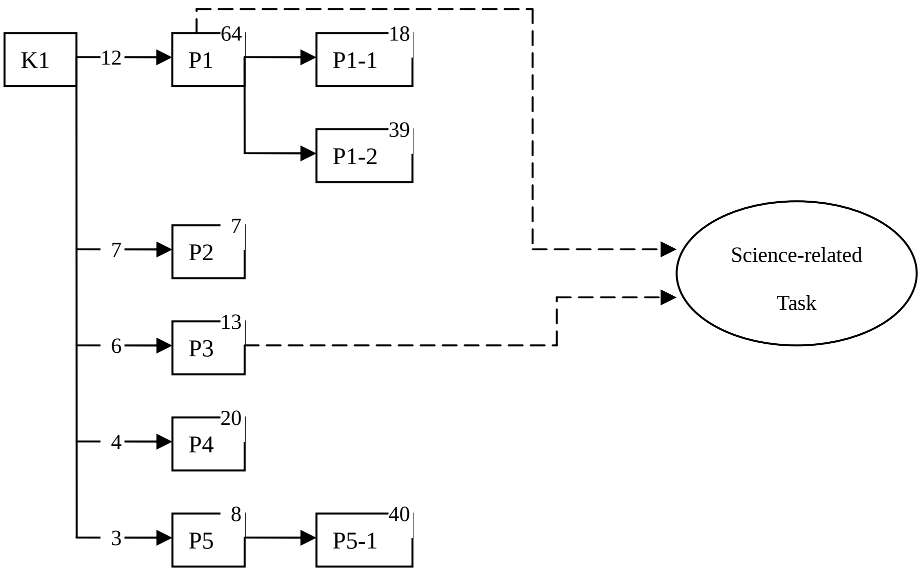
No.16


K1
12
K2
6
P1
9
P1-1
24
P1-2
8
5
4
P2
8
Science-related
Task
K3
22
P1
34
42

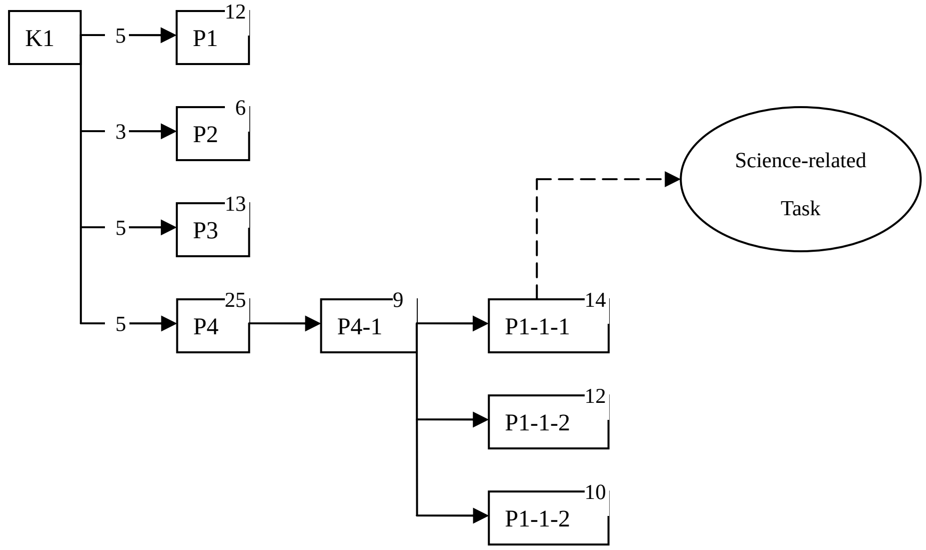
No.17


K1
7
P1
15
P1-1
22
P1-2
72
P1-3
23
P1-3-1
82
20
P1-3-1-1
3
P1-4
11
7
P2
123
P2-1
55
P2-2
27
P2-3
108
P2-4
52
Science-related
Task

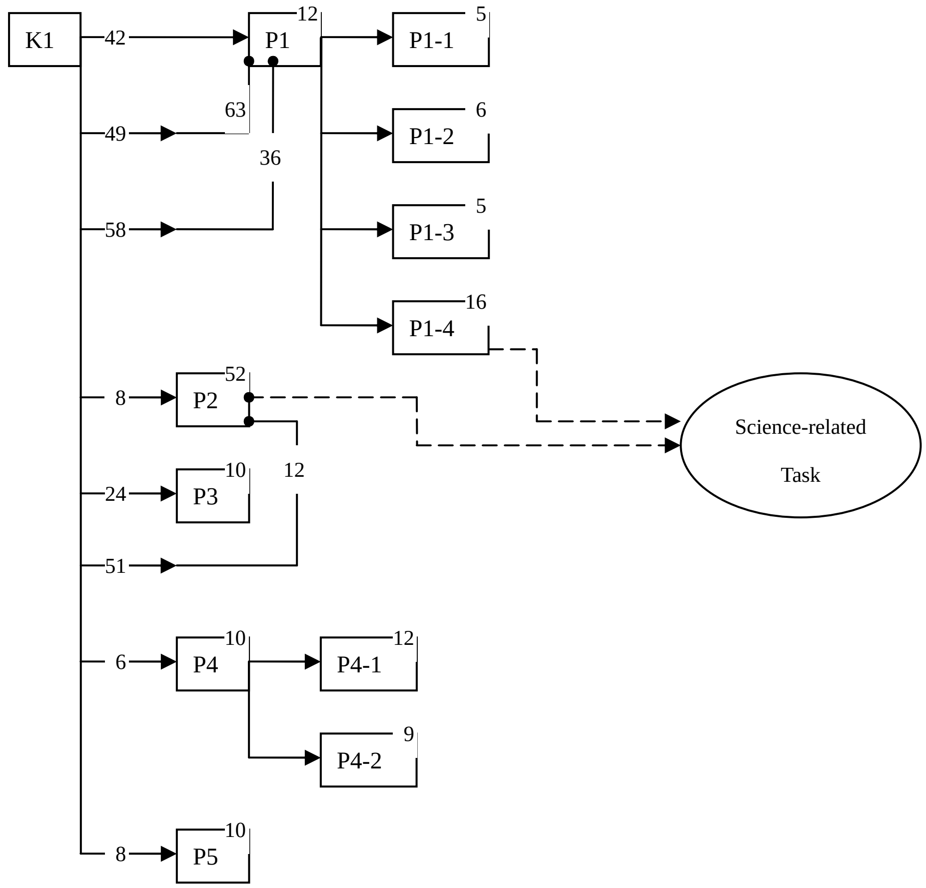
No.18


K1
12
P1
64
P1-1
18
P1-2
39
7
P2
7
6
P3
13
4
P4
20
3
P5
8
P5-1
40
Science-related
Task

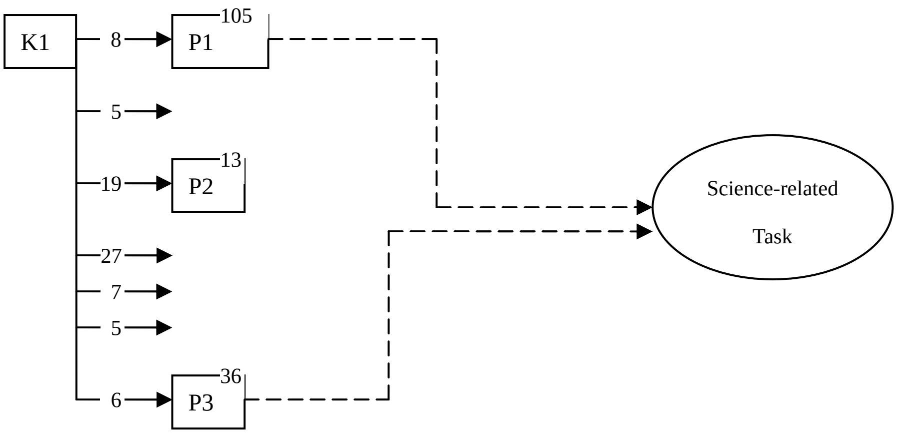
No.21


K1
5
3
5
5
P1
12
P2
6
P3
13
P4
25
P4-1
9
P1-1-1
14
P1-1-2
12
P1-1-2
10
Science-related
Task

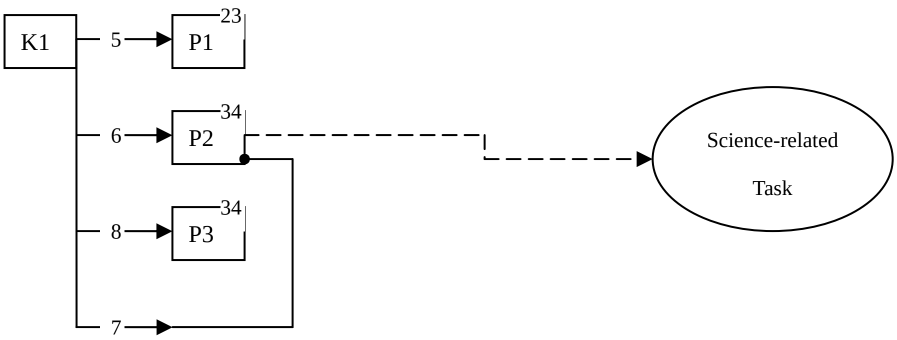
No.24


K1
42
49
58
8
24
51
6
8
P1
12
63
36
P1-1
5
P1-2
6
P1-3
5
P1-4
16
P2
52
12
P3
10
P4
10
P4-1
12
P4-2
9
P5
10
Science-related
Task

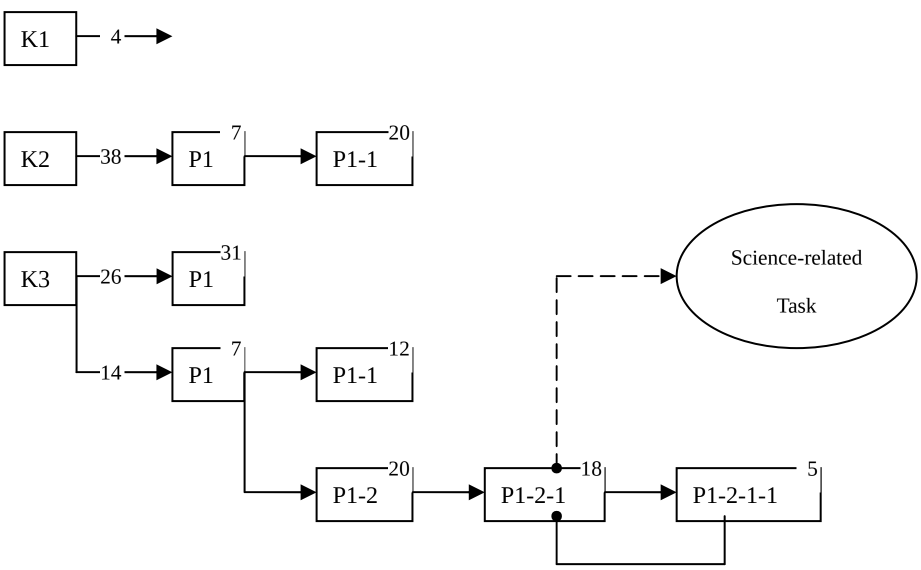
No.28



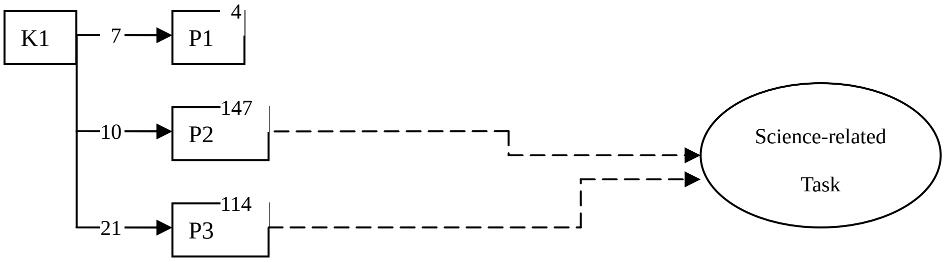
No.29



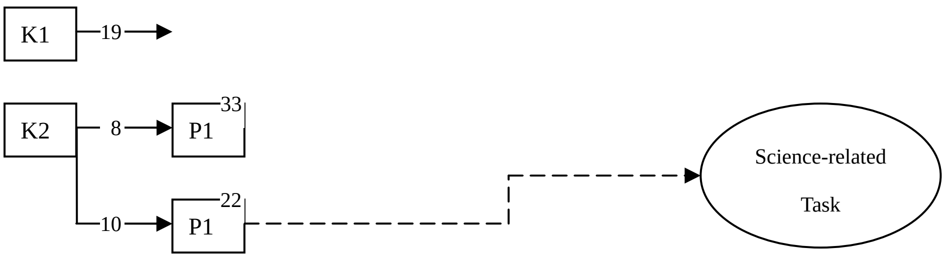
No.30



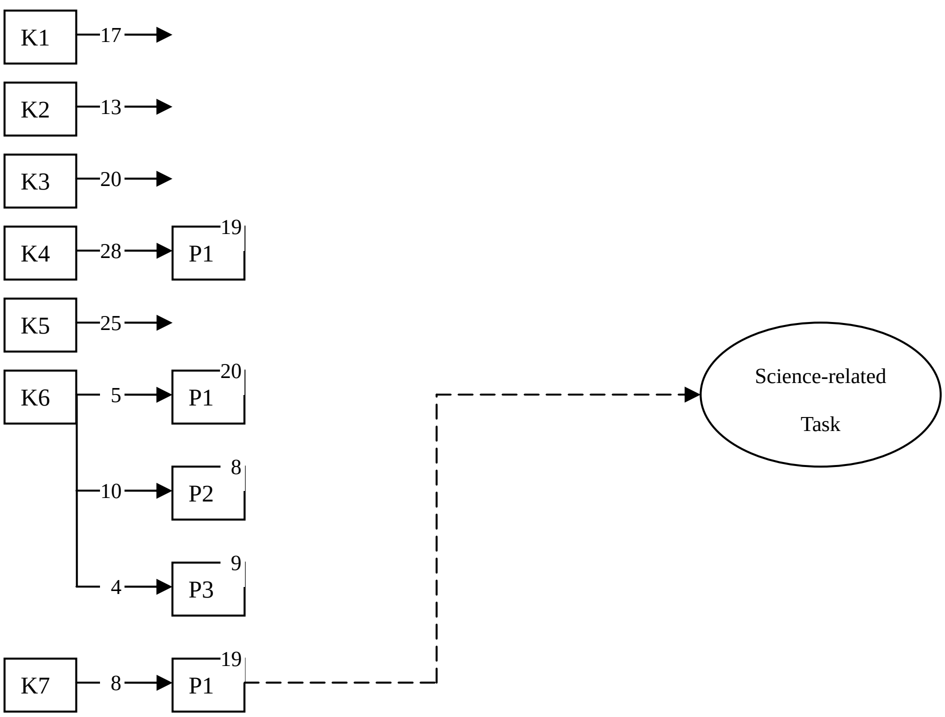
No.31



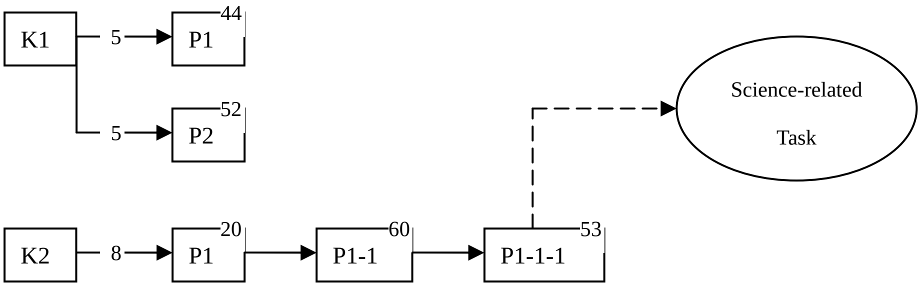
No.32



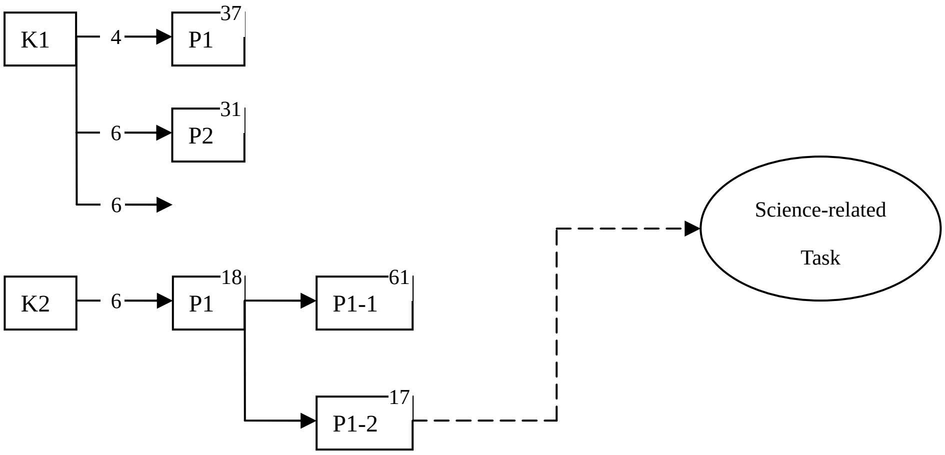
No.33



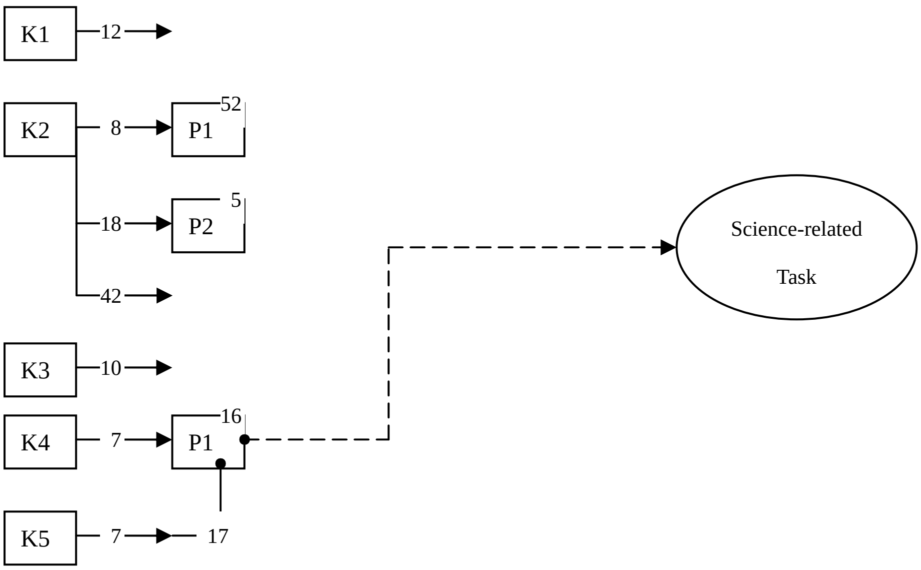
No.34



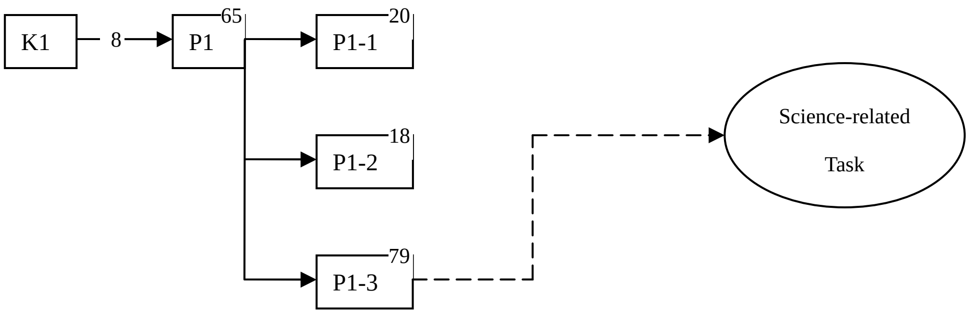
No.35



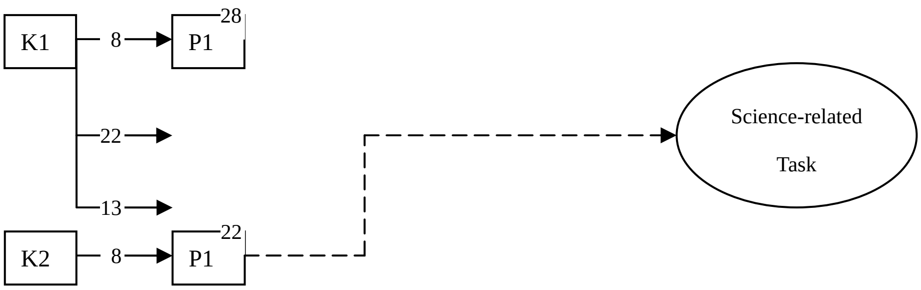
No.37



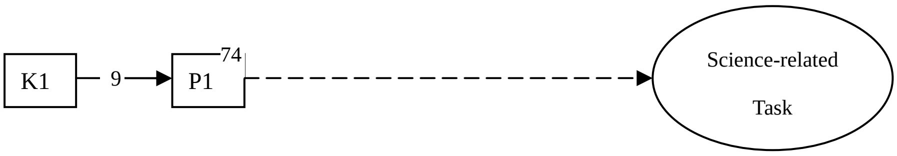
No.39



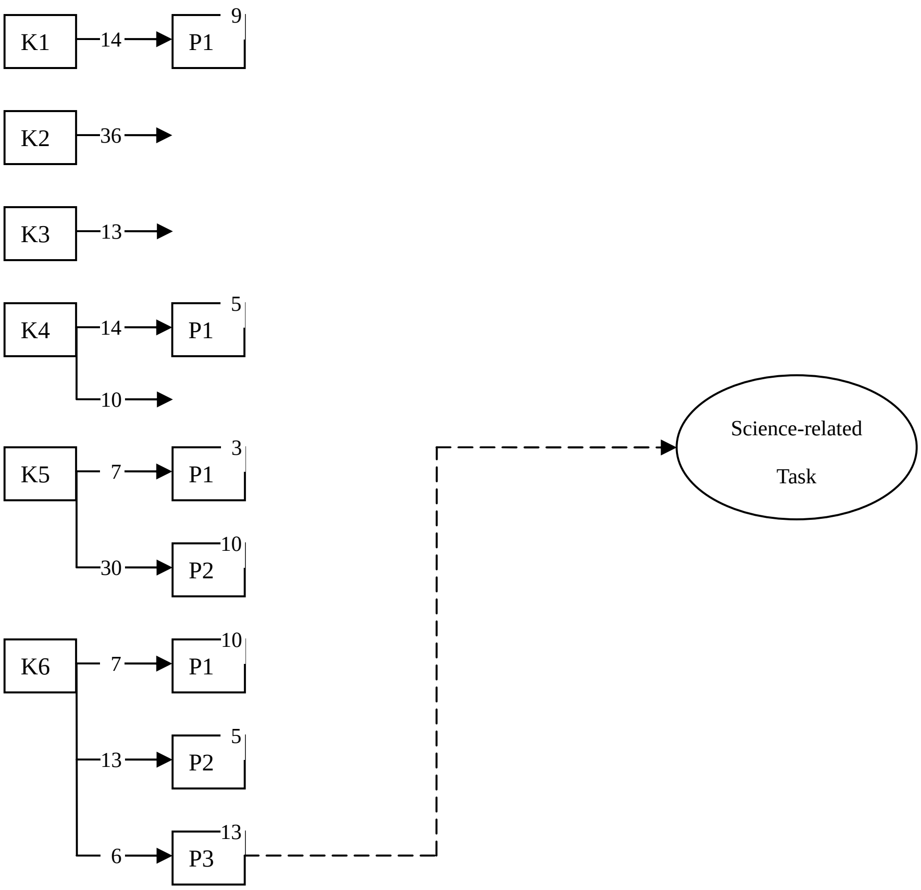
No.40



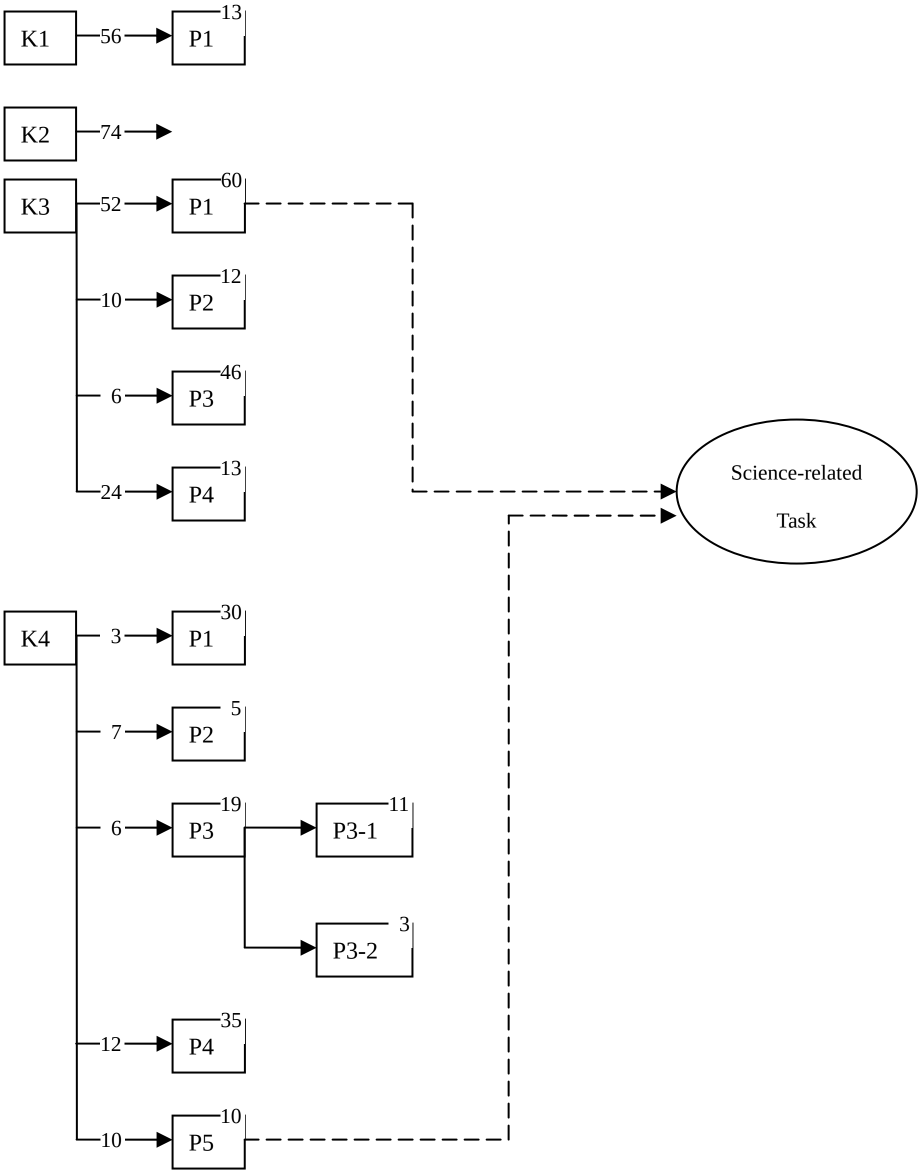
No.41



No.42

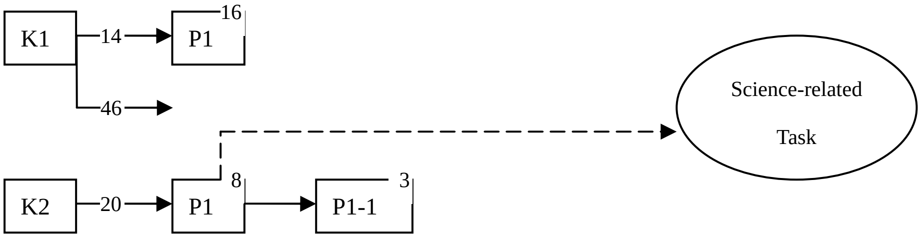

K1
14
P1
9
K2
36
K3
13
K4
14
P1
5
10
K5
7
P1
3
30
P2
10
K6
7
P1
10
13
P2
5
6
P3
13
Science-related
Task

No.44



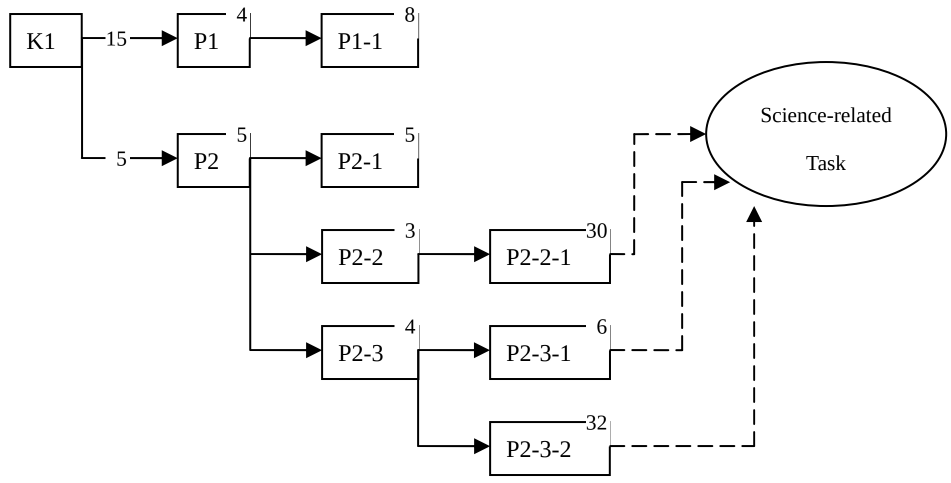
K1
56
P1
13
K2
74
K3
52
P1
60
10
P2
12
6
P3
46
24
P4
13
Science-related
Task
K4
3
P1
30
7
P2
5
6
P3
19
P3-1
11
P3-2
3
12
P4
35
10
P5
10

No.45

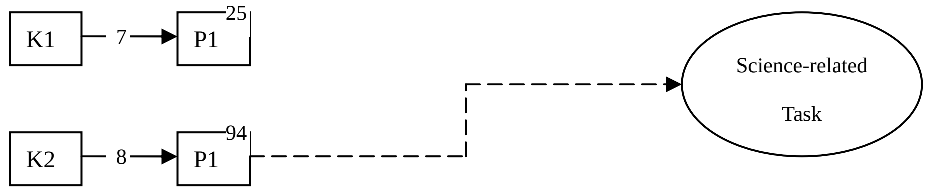


K1
14
P1
16
46
Science-related
Task
K2
20
P1
8
P1-1
3

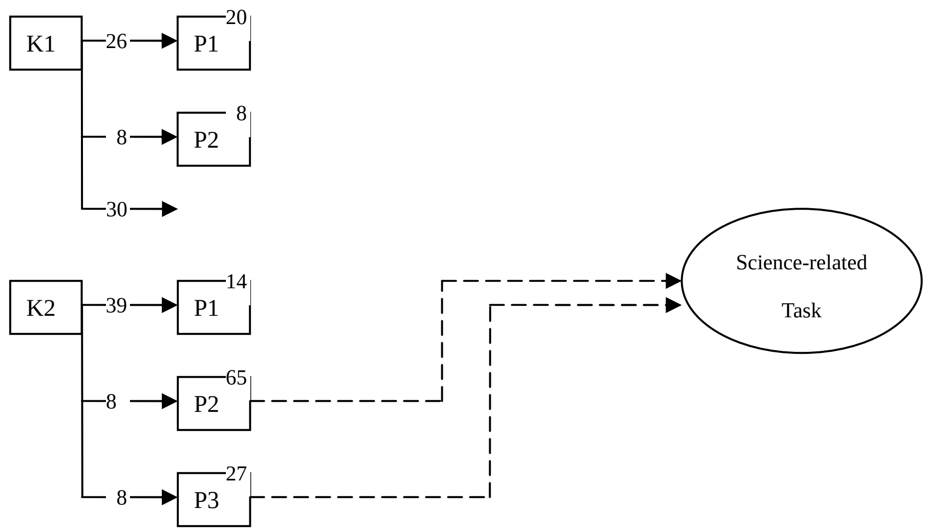
No.46



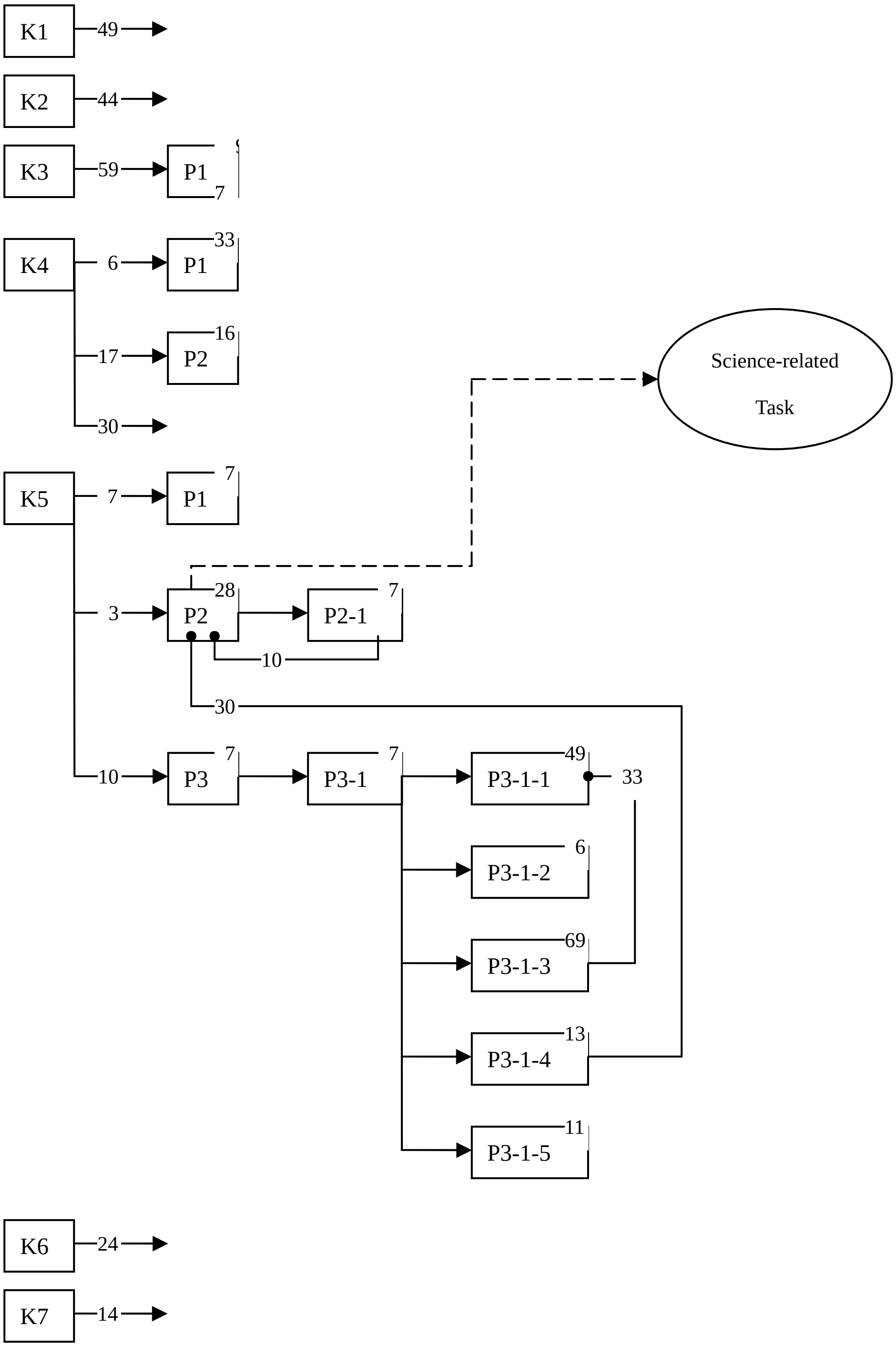
No.47



No.49

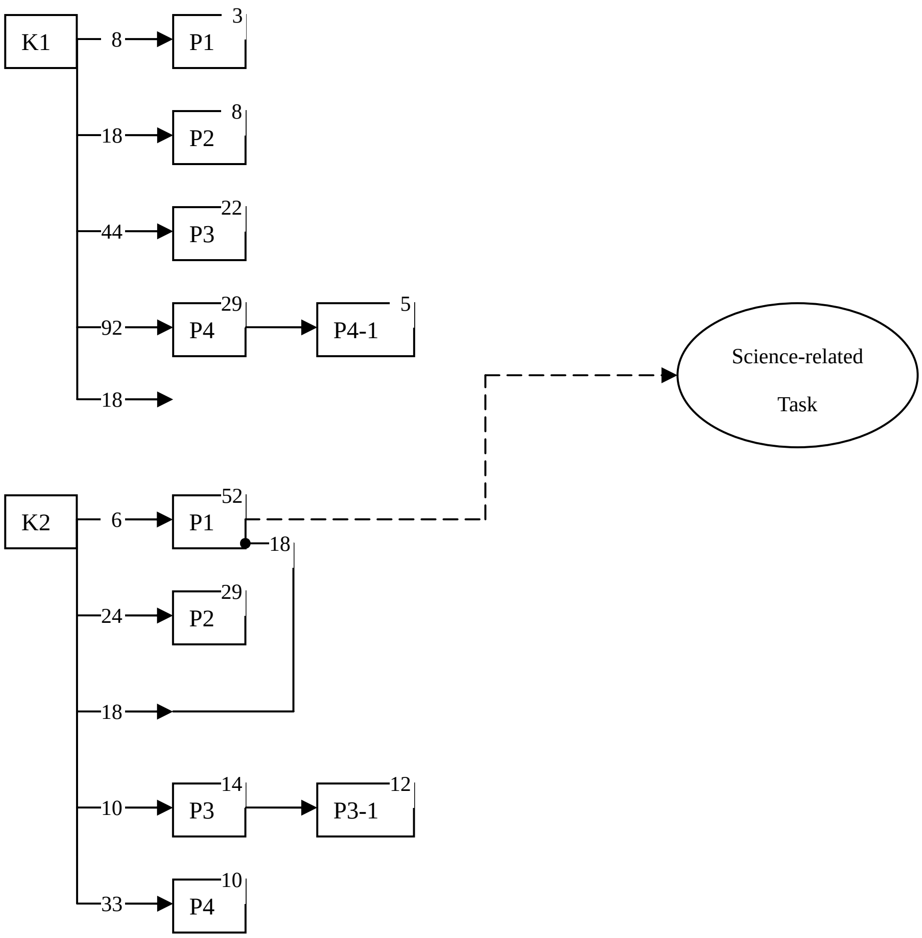


No.50

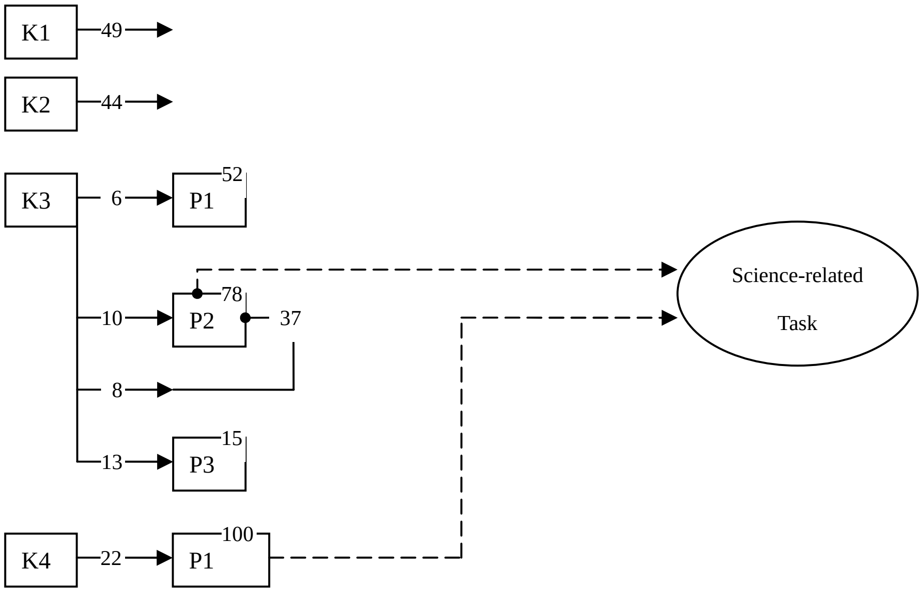


K1
49
K2
44
K3
59
P1
7
K4
6
P1
33
17
P2
16
30
K5
7
P1
7
3
P2
28
P2-1
7
10
30
10
P3
7
P3-1
7
P3-1-1
49
33
P3-1-2
6
P3-1-3
69
P3-1-4
13
P3-1-5
11
K6
24
K7
14
Science-related
Task

No.51


K1
8
P1
3
18
P2
8
44
P3
22
92
P4
29
P4-1
5
18
Science-related
Task
K2
6
P1
52
18
24
P2
29
18
10
P3
14
P3-1
12
33
P4
10

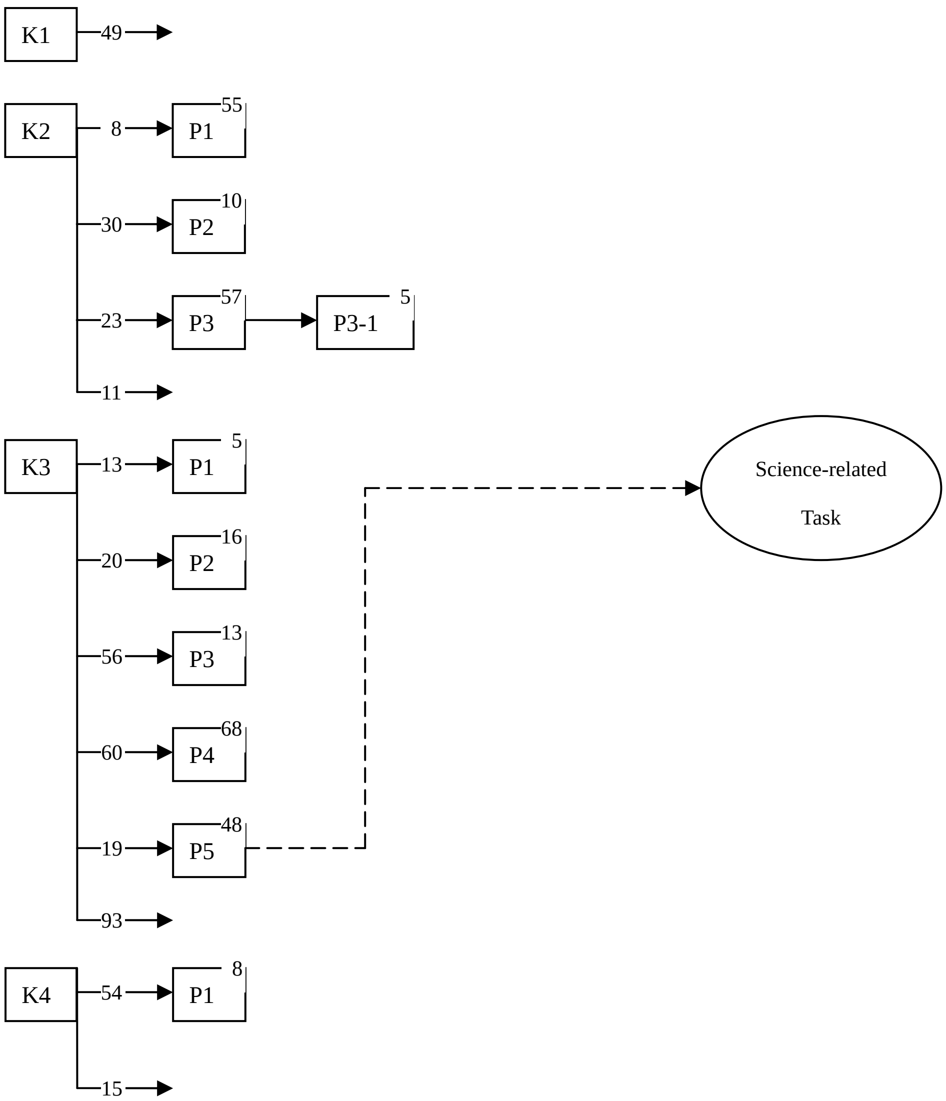
No.52


K1
49
K2
44
K3
6
P1
52
10
P2
78
37
8
13
P3
15
Science-related
Task
K4
22
P1
100

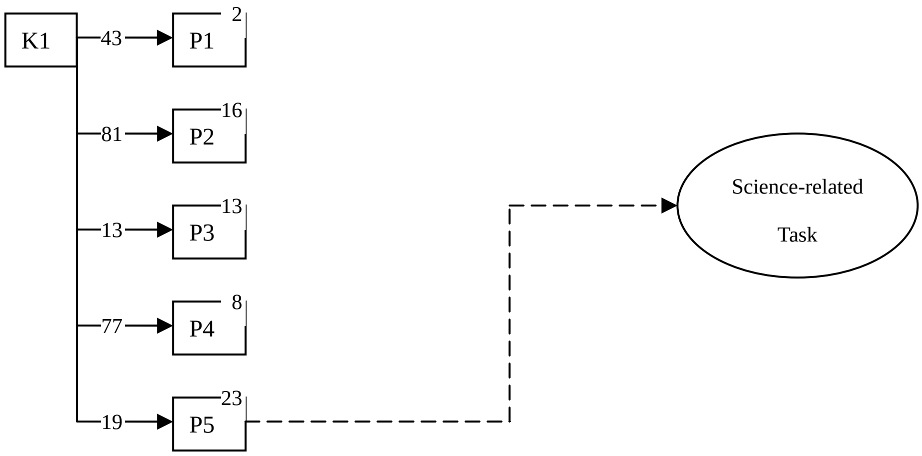
No.53


K1
20
P1
233
Science-related
Task

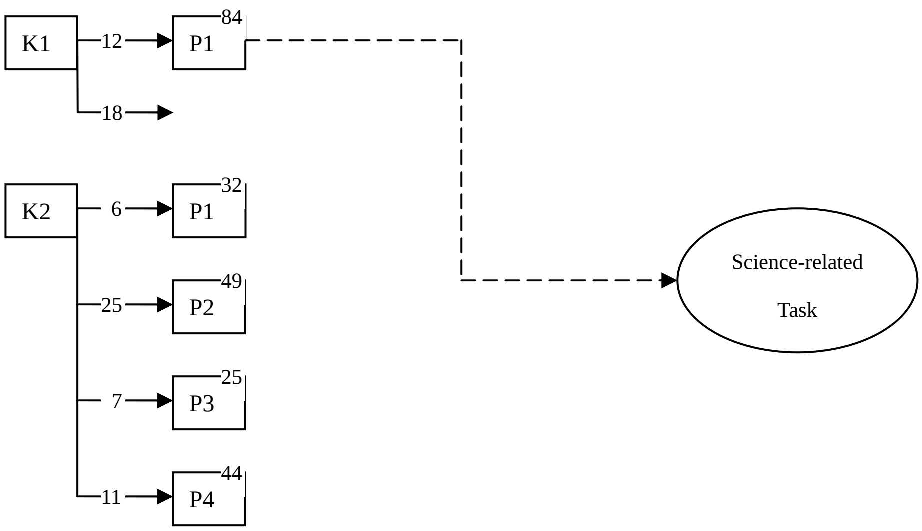
No.54


K1
49
K2
8
P1
55
30
P2
10
23
P3
57
P3-1
5
11
K3
13
P1
5
20
P2
16
56
P3
13
60
P4
68
19
P5
48
93
K4
54
P1
8
15
Science-related
Task

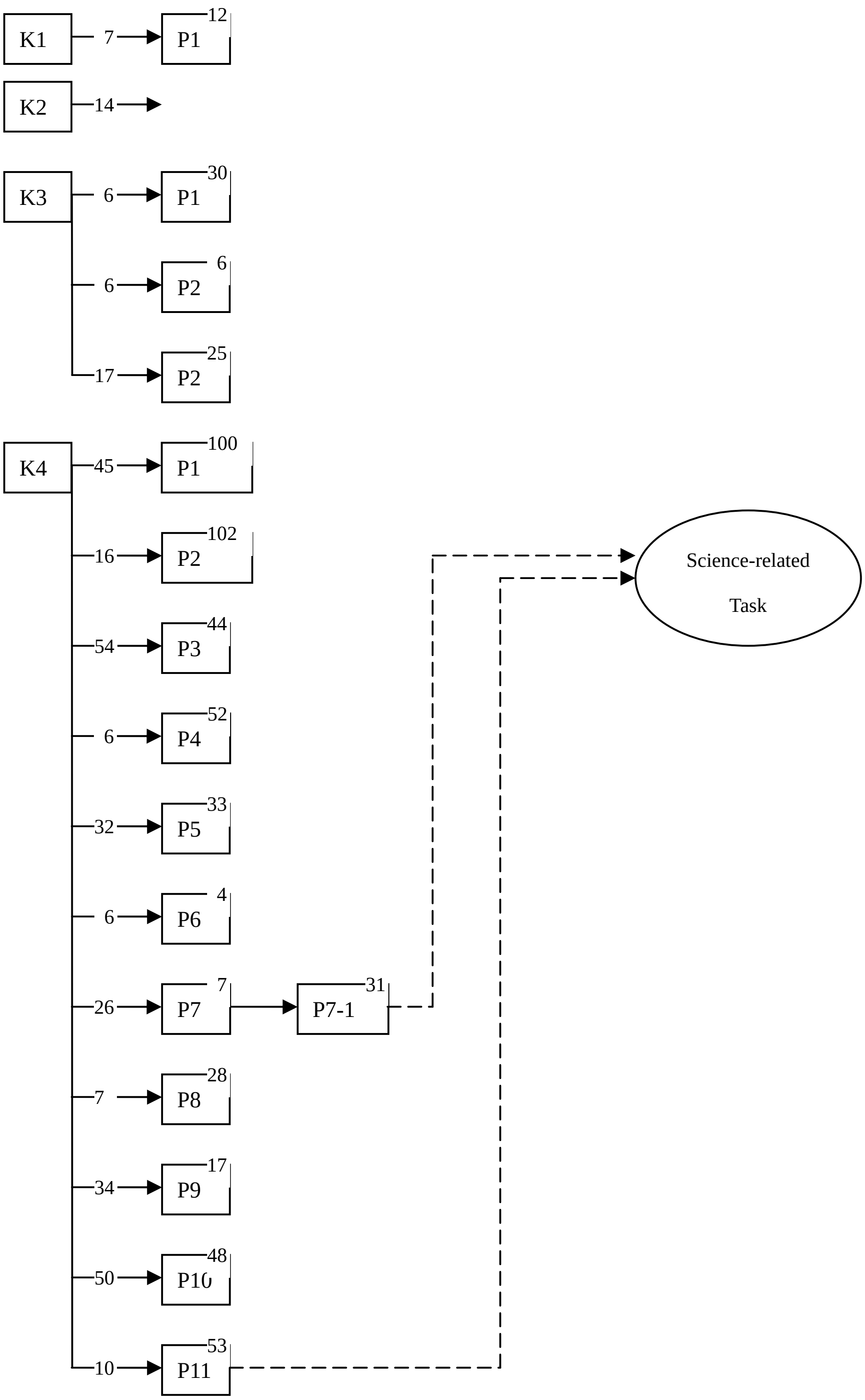
No.55


K1
43
P1
2
81
P2
16
13
P3
13
77
P4
8
19
P5
23
Science-related
Task

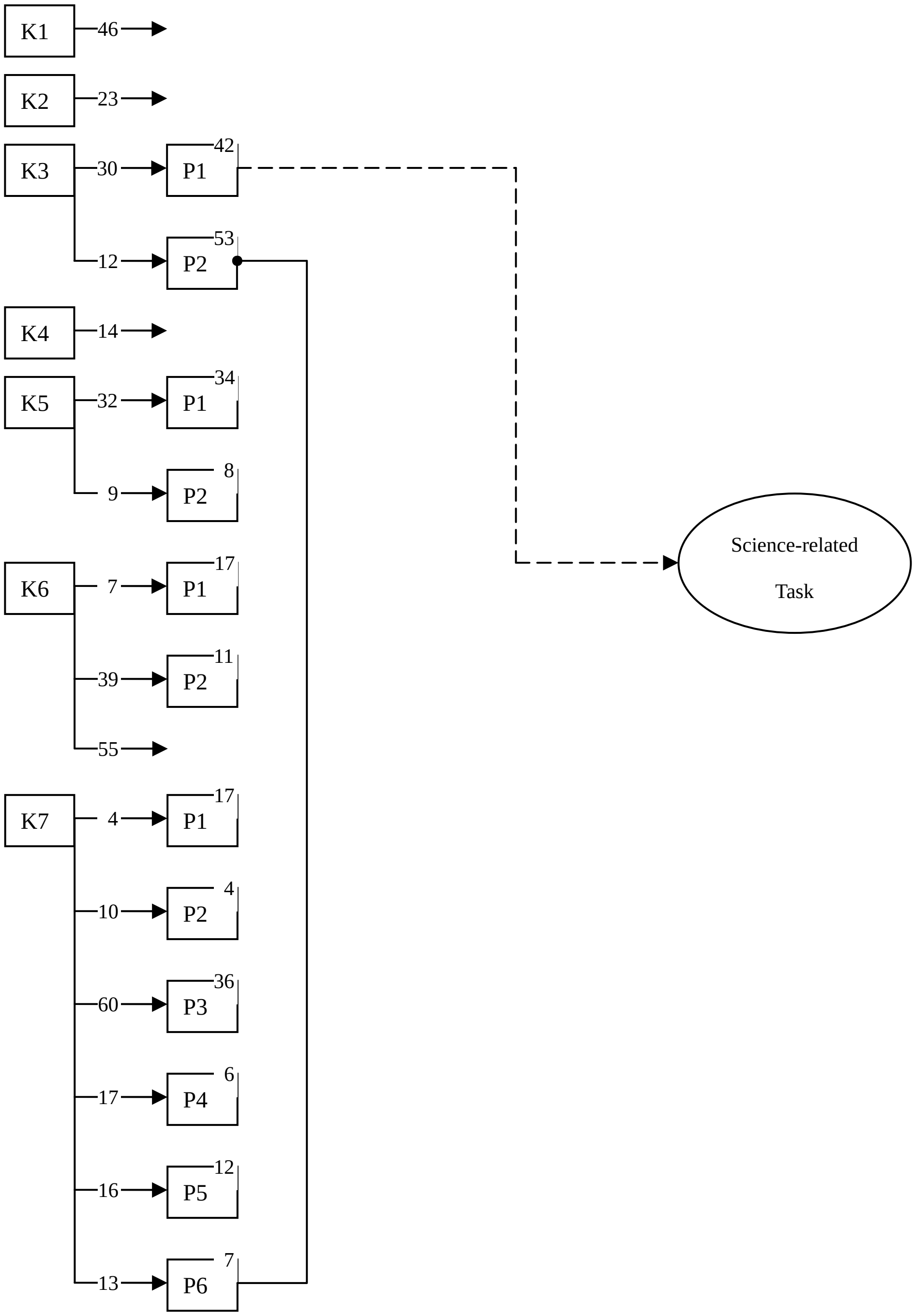
No.56


K1
12
P1
84
18
K2
6
P1
32
25
P2
49
7
P3
25
11
P4
44
Science-related
Task

No.57

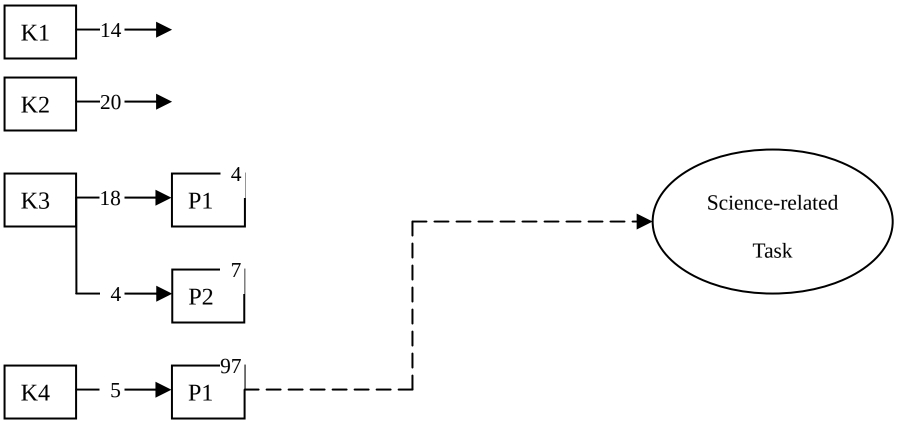

K1
7
P1
12
K2
14
K3
6
P1
30
6
P2
6
17
P2
25
K4
45
P1
100
16
P2
102
54
P3
44
6
P4
52
32
P5
33
6
P6
4
26
P7
7
P7-1
31
7
P8
28
34
P9
17
50
P10
48
10
P11
53
Science-related
Task

No.58

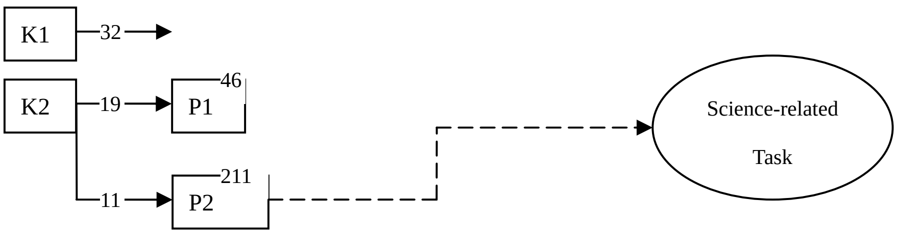


K1
46
K2
23
K3
30
P1
42
12
P2
53
K4
14
K5
32
P1
34
9
P2
8
K6
7
P1
17
39
P2
11
55
K7
4
P1
17
10
P2
4
60
P3
36
17
P4
6
16
P5
12
13
P6
7
Science-related
Task

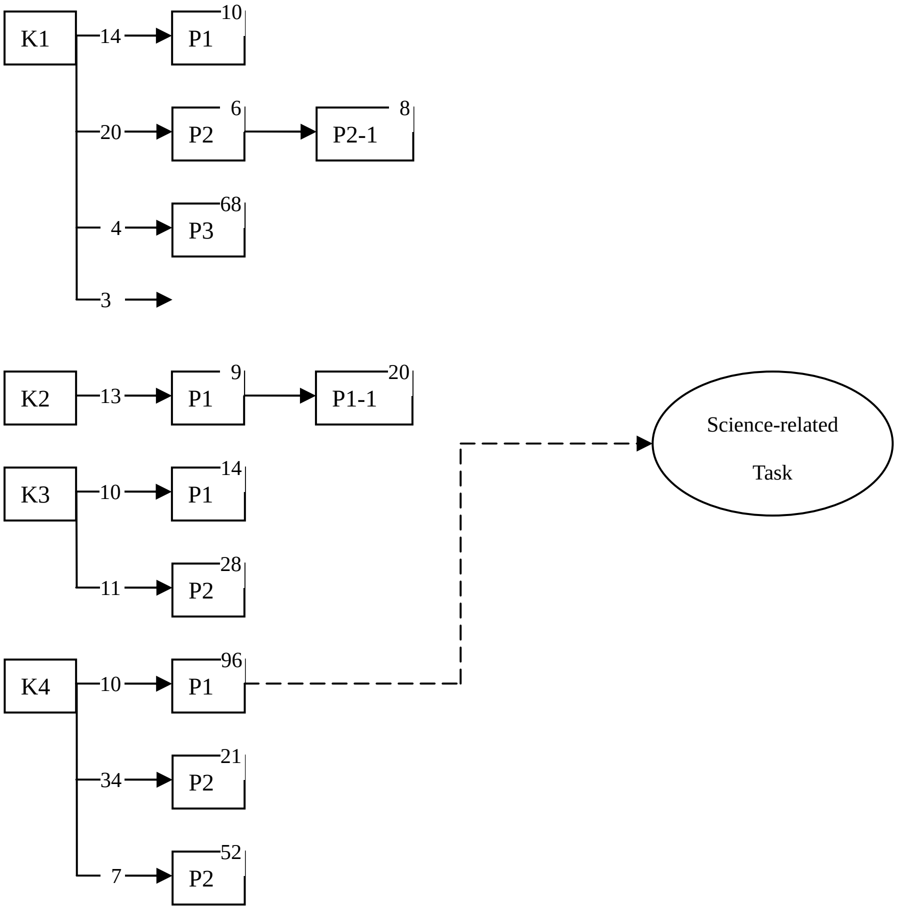
No.59


K1
14
K2
20
K3
18
P1
4
4
P2
7
K4
5
P1
97
Science-related
Task

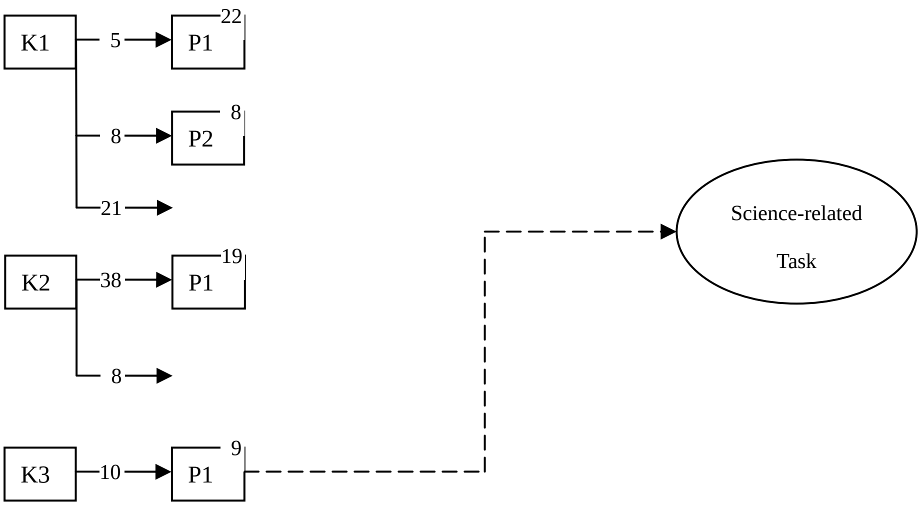
No.61


K1
32
K2
19
P1
46
11
P2
211
Science-related
Task

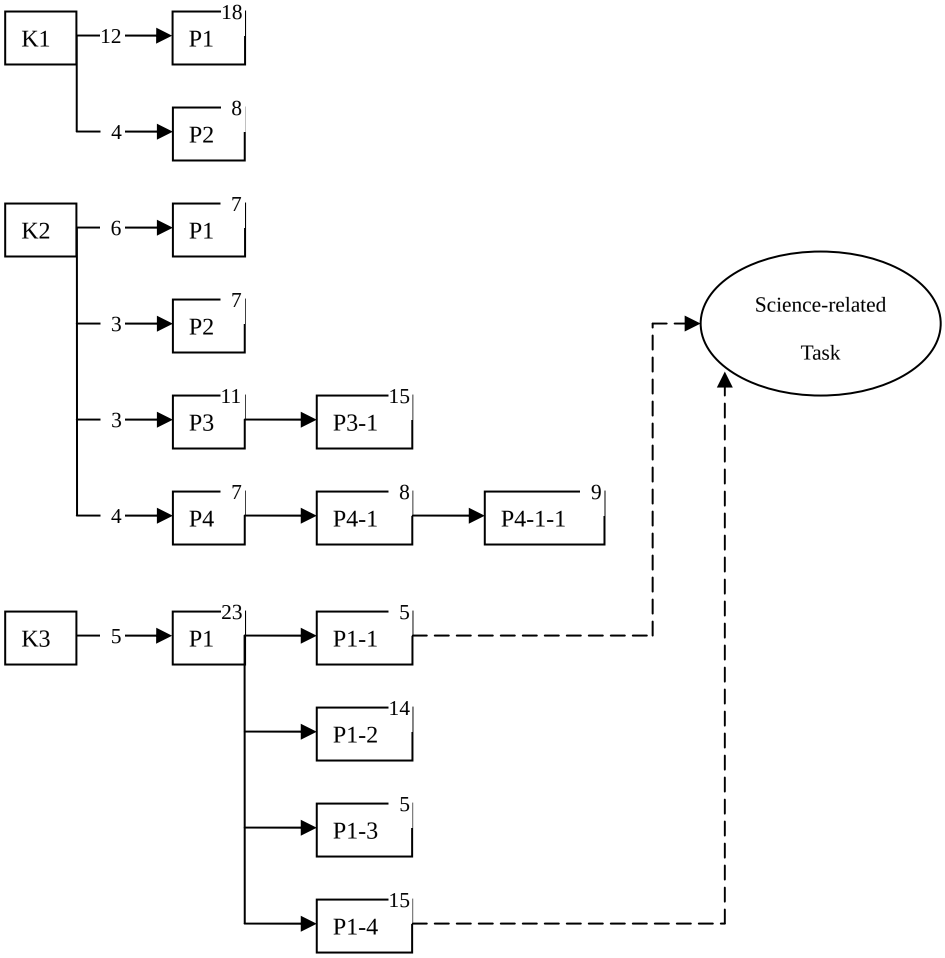
No.62


K1
14
P1
10
20
P2
6
P2-1
8
4
P3
68
3
K2
13
P1
9
P1-1
20
Science-related
Task
K3
10
P1
14
11
P2
28
K4
10
P1
96
34
P2
21
7
P2
52

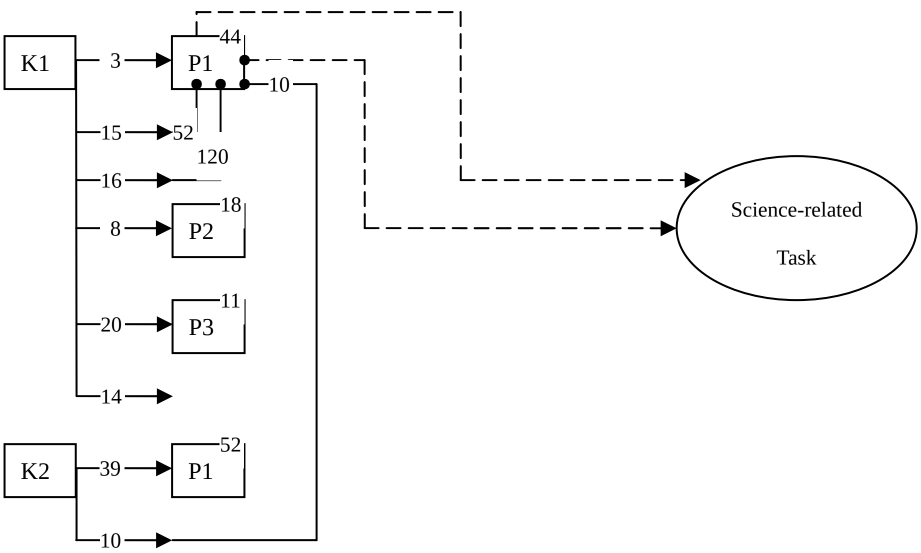
No.65


K1
5
P1
22
8
P2
8
21
Science-related
Task
K2
38
P1
19
8
K3
10
P1
9

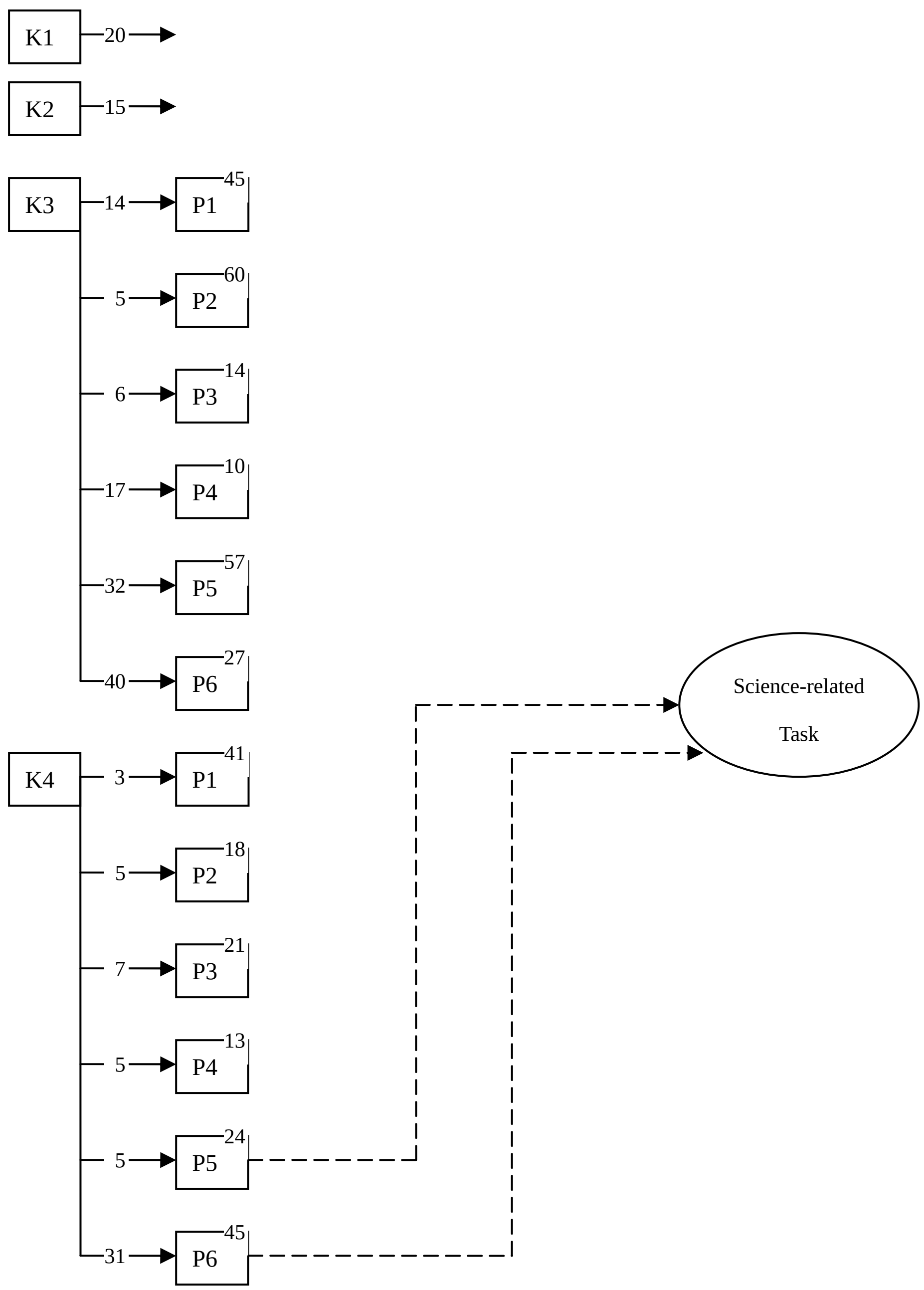
No.66


K1
12
P1
18
4
P2
8
K2
6
P1
7
3
P2
7
3
P3
11
P3-1
15
4
P4
7
P4-1
8
P4-1-1
9
K3
5
P1
23
P1-1
5
P1-2
14
P1-3
5
P1-4
15
Science-related
Task

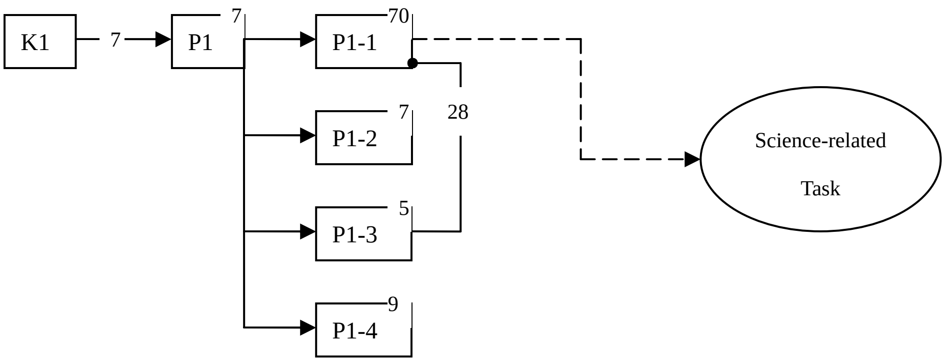
No.67


K1
3
P1
44
10
15
52
120
16
8
P2
18
20
P3
11
14
K2
39
P1
52
10
Science-related
Task

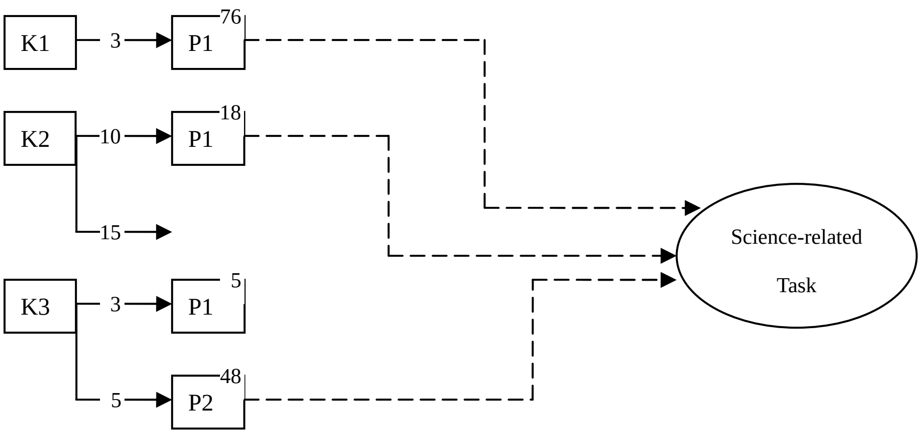
No.68


K1
20
K2
15
K3
14
P1
45
5
P2
60
6
P3
14
17
P4
10
32
P5
57
40
P6
27
K4
3
P1
41
5
P2
18
7
P3
21
5
P4
13
5
P5
24
31
P6
45
Science-related
Task

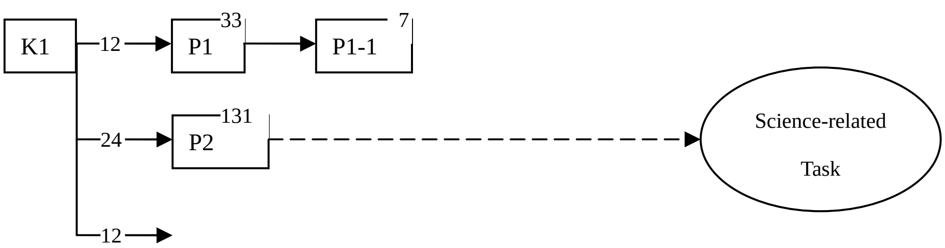
No.69



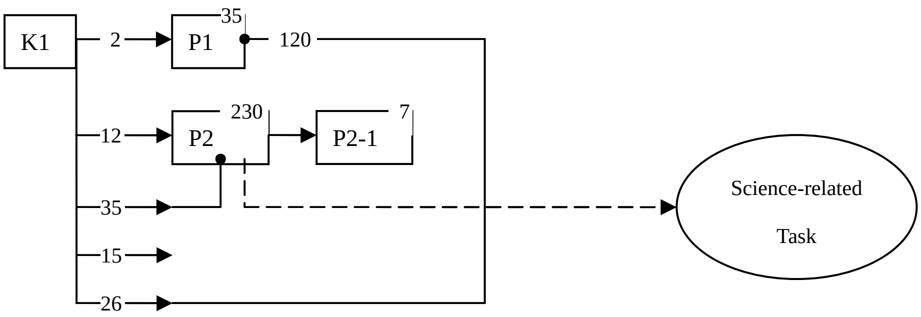
No.70



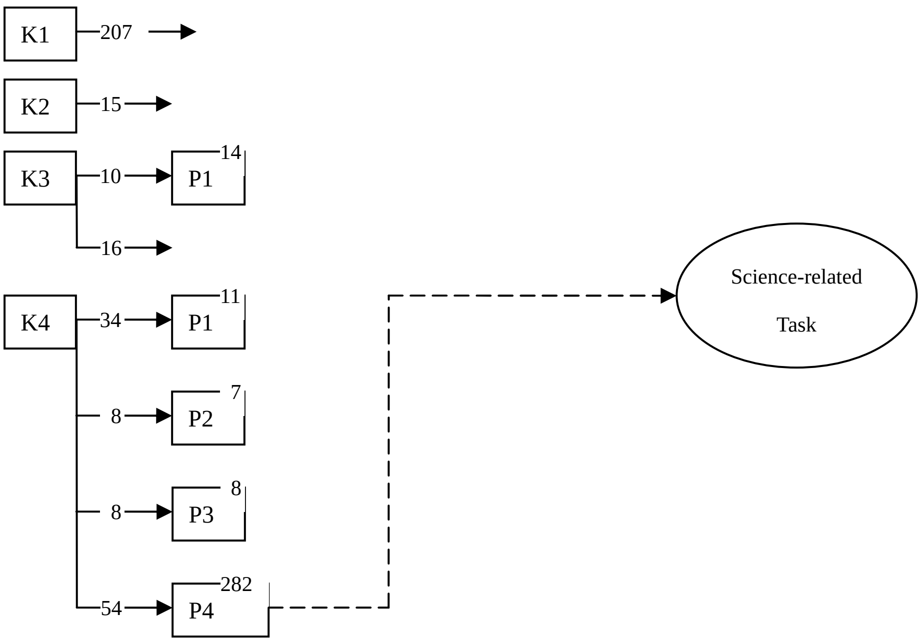
No.71



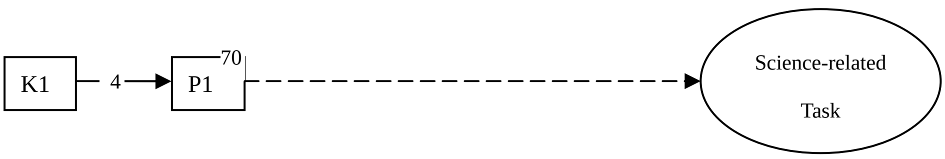
No.72



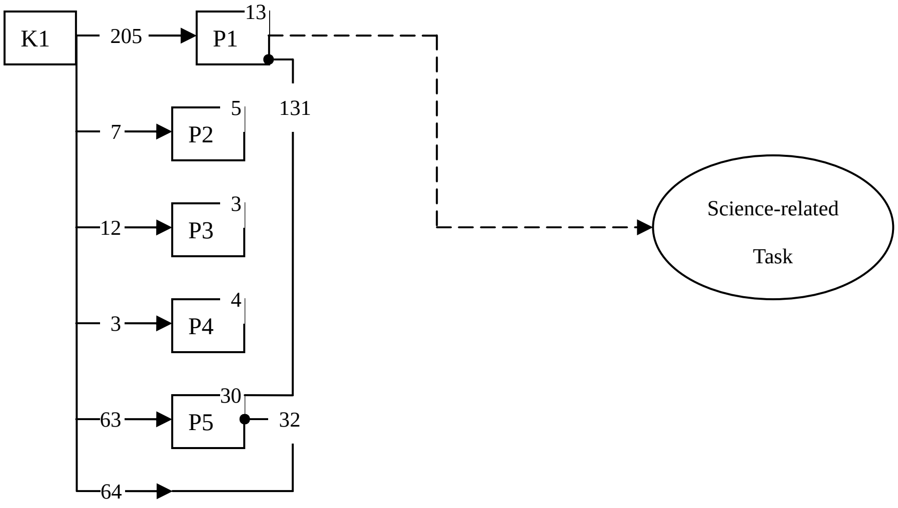
No.73



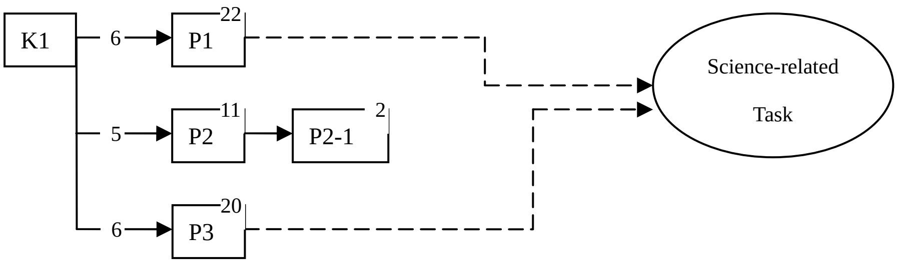
No.74



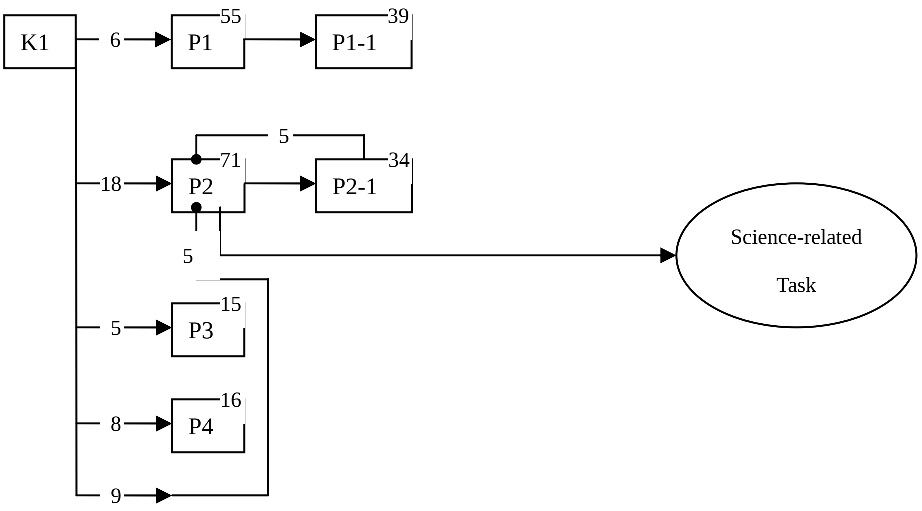
No.75



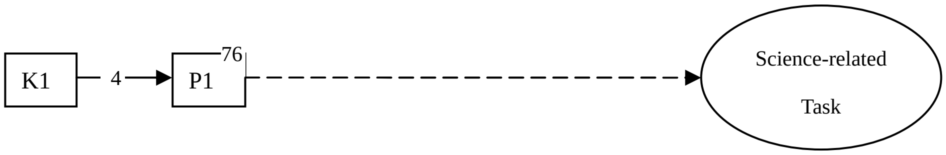
No.77



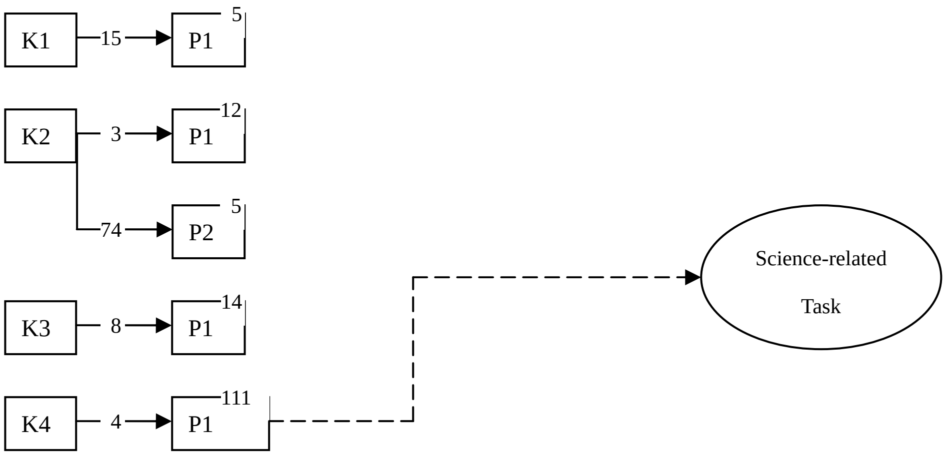
No.78



No.79


K1
4
P1
76
Science-related
Task

No.80


K1
15
P1
5
K2
3
P1
12
74
P2
5
K3
8
P1
14
K4
4
P1
111
Science-related
Task