DEVELOPMENT OF THE SPIRAL GRADUAL RELEASE OF RESPONSIBILITY (GRR) LEARNING MODEL TO ENHANCE LEARNING TRANSFER ABILITY OF CHINESE COLLEGE STUDENTS

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การพัฒนารูปแบบการเรียนรู้ด้วยโมเดลแบบเกลียวปล่อยความรับผิดชอบทีละน้อย (SPIRAL GRR) เพื่อเพิ่มความสามารถในการถ่ายโอนการเรียนรู้ของนักศึกษาวิทยาลัยจีน

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THE DISSERTATION TITLED

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BY

XUELIANG WU

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This research focused on third-year Economics students at Zhanjiang University of Science and Technology in Guangdong, China, and aims to enhance their ability to transfer learning. The objectives of the study are: (1) to define learning transfer and identify its current challenges through a review of literature and interviews, (2) to develop a Spiral Gradual Release of Responsibility (GRR) Learning Model that integrates strategic learning, knowledge spiral theory, and the GRR framework to improve learning transfer, and (3) to implement this model in an Econometrics course to evaluate its effectiveness. The research utilized qualitative and quantitative methods, including literature analysis, interviews, and statistical evaluations of tests and self-assessments. Findings revealed that learning transfer is categorized into horizontal and vertical transfer. The experimental group showed a clearer improvement in transfer test scores compared to the control group, particularly with higher difficulty tasks. After each unit, self-assessments indicated that students' acquisition of knowledge and strategies generally increased, though Unit 4 showed slightly lower results due to its complexity. Overall, the Spiral GRR Learning Model proved more stable and effective than traditional methods.

Keyword : Learning Transfer Ability; Spiral GRR Learning Model; Knowledge; Cognitive Strategies; Metacognitive Strategies.

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CHAPTER 1
INTRODUCTION

1.1 Background

1.1.1Transfer of learning is very important

The appeals of era development: with the rapid development of the scientific and technological revolution in the information age, new knowledge and achievements are constantly emerging, and the amount of knowledge is rapidly expanding, leading to the phenomenon of "knowledge explosion"(Liu, 1999). According to United Nations Education Scientific and Cultural Organization(UNESCO) statistics, the scientific knowledge accumulated by humans in the past 30 years accounts for 90% of the total scientific knowledge throughout history, while the scientific knowledge accumulated in the previous millennia only accounts for 10%(Wu, 2009). Regardless of how knowledge is defined, it is no longer possible for teachers to impart all the knowledge in the existing system to the next generation(Holmes & McLean, 2001), And the focus of education is shifting from “teaching” to “learning” today based on what people need to learn. The NRC (2000) recommends that the goal of education shift from an emphasis on comprehensive coverage of subject matter to helping students develop their own intellectual tools and learning strategies. More important though is having the skill to learn on one’s own after leaving college. The most-important skill will empower you for a lifetime and should be one of your highest priorities for attending college(Wirth & Perkins, 2008). The enhancement of students’ transfer of learning can achieve meaningful learning on their own(Jing, Li, & Hou, 2022).

The intrinsic demand of higher education: an important goal of education is to promote transfer(Mayer, 2002; Mayer & Wittrock, 1996). Transfer of learning is the ultimate pillar that education must rely on(Niu & Nie, 2010). Due to the significant difference between the learning situation and the final background of the application, the purpose of education cannot be achieved unless transfer occurs(Perkins & Salomon, 1992). In addition, many studies have shown that transfer of learning is a form of higher-order thinking(An, 2014; Brookhart, 2010; Cheng & Wei, 2021; Ma & Yang, 2022; Williams, 2003; Zhang, 2010). and students' higher-order thinking skills are the main goal of current educational reform efforts(Zoller, 2000).

Realistic dilemma: transfer can enable students to apply their knowledge to solve new problems and promote the learning of new topics(Mayer & Wittrock, 1996), which has a direct promoting effect on improving the development of problem-solving abilities(Niu & Nie, 2010). Therefore, transfer is crucial for education, but research suggests that transfer often does not occur, especially "far" transfer(Perkins & Salomon, 1992). A number of studies conducted to explore the potential benefits of learning programming on problem-solving skills and cognitive processes have reported inconclusive or negative outcomes (Pea & Kurland, 1984; Salomon & Perkins, 1987). Students generally lack awareness of restructuring existing knowledge systems and skills, and teachers also tend to overlook guiding and imparting cognitive skills and learning strategies. These two factors have contributed to the dilemma in cultivating students' transfer of learning (Jing, Li and Hou, 2022). In summary, transfer is often not easy to occur.

1.1.2 Cognitive and metacognitive strategies can enhance students' learning transfer ability.

Learning strategies covers cognitive and metacognitive strategies (Fooladvand, Yarmohammadian, & Zirakbash, 2017). A cognitive strategy is a means to achieve a cognitive goal (such as understanding or remembering) and involves potentially conscious and controllable activities (Pressley & Harris, 2009). Cognitive approaches such as repetition, categorization, and expansion of knowledge (Weinstein, Husman, & Dierking, 2000) are tailored to specific tasks as they focus on the unique cognitive processes needed for different learning objectives. For instance, when students aim to comprehend a non-fiction text thoroughly, employing text underlining as a cognitive technique is fitting for this purpose, as it targets the specific cognitive processing demands of the task. Additionally, the experimental manipulation strategy can be utilized when performing scientific experiments. Therefore, their transferability is limited(Schuster, Stebner, Leutner, & Wirth, 2020). Even so, but researches has shown that cognitive strategies and metacognitive strategies can improve students' performance and achievement(Fooladvand et al., 2017; Saeid & Mehrabi, 2013; Yang, 2005), and better learning achievement is conducive to knowledge transfer(Pham & Huynh, 2018).

Metacognitive tactics can be categorized into three main areas: planning, monitoring, and self-assessment (Flavell, Miller, & Miller, 2002; Schraw & Dennison, 1994). While these strategies do not directly engage with the processing of information or motivational aspects, they are crucial for ensuring that learners effectively employ cognitive and motivational regulation techniques (Leopold & Leutner, 2015). Metacognitive strategies are designed to oversee and manage cognitive or motivational approaches across various learning activities, and studies have shown that they can boost performance in different areas (Carretti, Caldarola, Tencati, & Cornoldi, 2014; Ohtani & Hisasaka, 2018; Zepeda, Hlutkowsky, Partika, & Nokes-Malach, 2019). Consequently, metacognitive abilities are considered to be broadly applicable (Schuster et al., 2020; Veenman & Verheij, 2003), and once acquired, they can be adapted to new situations and tasks. For example, these skills are equally beneficial for comprehending non-fiction literature and conducting scientific experiments (Schuster et al., 2020).

Learning strategies optimizes the process of transfer(McKeachie, 1987). If people understand that a strategy has a positive impact on their performance, they are more likely to continue to use this strategy(Pressley, Borkowski, & O'Sullivan, 1985). - enriches experience in using strategies.

In summary, it can be generalized that learning strategies promotes transfer from three aspects. First, the learning of strategies promotes knowledge transfer by improving knowledge understanding; Second, the learning of strategies promotes the transfer of metacognitive strategies; Third, the learning of strategies promotes the experience in applying strategies. For example, research by Schuster el ta.(2020) shows that strategic training increase the use of strategies.

1.1.3 GRR and spiral GRR as means helps students learn something from teacher.

GRR means gradual release of responsibility. This means that when the content is new and unfamiliar, the cognitive responsibility is primarily the teacher's. As the learner acquires knowledge, the intellectual weight shifts(Fisher & Frey, 2013). In the GRR model, teachers, as more knowledgeable individuals, begin to build scaffolding for students. As students' abilities improve, teachers gradually remove the scaffolding, allowing them to independently complete tasks(Man & Ye, 2004) and solve problems independently.

According to research by Fisher and Frey (2021), the GRR teaching not only teaches students how to do something, but also allows them to analyze whether the use of learned knowledge has been successful. That is to say, the teacher teach students cognitive strategies and metacognitive awareness.

According to McVee, Shanahan, Pearson and Rinker (2015), the learning process has the essence of iteration. Therefore, several rounds of GRR iteration process can be arranged in teaching practice, but the content of each round is relatively advanced to a higher level, with an upward and forward direction, presenting a spiral structure, namely the spiral GRR. We found no research integrate GRR, spiral structure, learning strategies to develop a learning model to enhance students' transfer.

1.1.4 Why choose Econometrics?

In the economic education system, as a bridge connecting theoretical and empirical economics, econometrics is increasingly showing its importance (Cladera, 2021) and aims to reveal the causal relationships between economic variables through quantitative analysis and explain and predict economic phenomena (Angrist & Pischke, 2017). For students majoring in economics, learning econometrics is crucial for deeply understanding economic data, making economic forecasts, and evaluating the effects of economic policies.

After learning econometrics, students apply the learned theories and methods to solve real-world problems (McKee & Orlov, 2021), that is, to transfer and apply the knowledge and experience to new problem contexts. Case studies and empirical analysis are important means in learning. However, research has found some problems. Even if the information is accessible to individuals, it may not be utilized. In other words, even if declarative knowledge or procedural knowledge is available, learners may not use them (Fayol, 1994). In econometrics, traditional teaching methods often emphasize theoretical explanations and model derivation, but this "cramming" teaching method often fails to enable students to deeply understand and flexibly apply the knowledge they have learned. Especially when facing complex economic problems, students often lack the ability to apply theoretical knowledge to practical problems (McKee & Orlov, 2021).

1.2 Research Problems

This research hope the GRR model can be used to students' knowledge and strategies learning and then develop students' transfer of learning. By analyzing the theories and reviewing the literature, the research ideas are clarified and the following three problems to be solved are proposed. It is hoped that this research can provide some ideas and suggestions for strategies learning and transfer of learning in econometrics.

1. What are the definition and contents of transfer of learning, and problem situation for college students?

2. How to develop a learning model combining the GRR with the spiral structure for enhancing college students' learning transfer ability?

3. How to validate the effectiveness of this spiral GRR learning model in enhancing college students' learning transfer ability?

1.3 Research Objectives

The main purpose of this study is:

1. To research the definition and contents of transfer of learning, and problem situation for college students;

2. To develop a learning model that integrates spiral structure, GRR model, and strategic learning, with the aim of enhancing college students' learning transfer ability;

3. To assess the effectiveness of the spiral GRR learning model in improving college students' learning transfer ability following its implementation in econometrics course.

1.4 Significance of the Study

School education cannot teach students all the knowledge, so students need to learn how to learn. Learning in school is not only to learn knowledge, but more importantly to acquire and accumulate learning strategies, develop transfer of learning, and enable to apply them in solving problem and have a better performance in learning new topics. The focus of this study is on developing a learning model and validate its effectiveness by evaluating transfer of learning in Econometric.

The significance of the study is specifically reflected in:

1. For students, using the learning model to carry out classroom activities can help them gradually accumulate econometrics knowledge, strategies and positive learning experience, improving learning interest and learning efficiency, forming a good cognitive structure of knowledge based on understanding, and exploring transfer of learning.

2. From the perspective of educators, the exploring facilitates teachers' ability to better design classroom activities that focus on strategies learning and to understand the mechanism of transfer of learning, stimulating teaching enthusiasm.

1.5 Scope of the Study

The present study confined itself to the following:

1. The primary focus of this research is on college students' transfer of learning in econometrics, including

1) Vertical Transfer -the performance in solving problem after learning

2) Horizontal Transfer -the performance in self-learning a new topic in econometrics(Pre-study Task Test)

2. The second focus of this study is on college students' transfer of learning including:

1) transfer of knowledge

2) transfer of experience in using cognitive strategies

3) transfer of metacognitive strategies

3. The population of this study includes 271 third year students majoring in economics from six classes at Zhanjiang University of Science and Technology(Z University) in Guangdong Province, China. There are approximately 45 students in each classroom.

4. The sample is two classes (89 students) of third year students majoring in economics from Z University. Randomly selecting two classes from six classes using cluster sampling method. One class is randomly assigned to an experimental group(44 students), using the learning model developed in this research, while the other class is a control group(45 students), using traditional learning method.

3. Variables

1) Independent Variable(IV) is: the learning model which divided into two types:

(1) The learning model developed in this study combines the GRR with the spiral structure, where the three stages of learning corresponding to knowledge,

cognitive strategies, and metacognitive strategies are aligned with the three cycles of the spiral structure, with the GRR model being applied in each cycle.

(2) The traditional learning method.

2) Dependent Variable(DV) is: learning transfer ability.

(1) Vertical Transfer -The performance in solving problem after learning

(2) Horizontal Transfer -The performance in learning a new topic.

1.6 Definition of Terms

1.Knowledge

Knowledge refers to the content of migration involved in the first layer of the spiral structure, which specifically pertains to academic knowledge. This includes, but is not limited to, facts, principles, concepts, theories, and methodologies. Such knowledge forms the basis for higher-level cognitive activities, such as critical thinking, problem-solving, and innovation.

2. Cognitive and metacognitive strategies

Learning strategies refers to cognitive strategies and metacognitive strategies.

Cognitive strategies refer to techniques or methods that learners use to better understand knowledge. These strategies are directly involved in the manipulation and organization of knowledge, including 1) Attention Focusing; 2) Elaboration; 3)Organization; 4) Comparison; 5) Problem-Solving; 6) Critical Thinking; 7) Memory Techniques.

Metacognitive strategies refer to strategies that regulate, monitor, and evaluate the cognitive process. These strategies are about being aware of and managing how you learn and think. include: 1) Goal Setting; 2) Planning; 3) Monitoring; 4) Evaluating; 5) Reflection; 6) Adjustment; 7) Self-Questioning; 8) Use of Wait Time.

3. GRR

GRR means Gradual Release of Responsibility, which involves teachers transferring the cognitive load from themselves to students in the classroom, including four steps:

1) Focused instruction

2) Guided instruction

3) Collaborative Learning

4) Independent Learning

4. Spiral structure

The "Spiral Structure" refers to a cyclical and progressive learning or developmental model.

1) the first cycle involves knowledge(specific subject matter or content) acquisition ;

2) the second cycle includes a review of previous knowledge and the learning of cognitive strategies;

3) the third cycle encompasses a review of previous knowledge and cognitive strategies, as well as the introduction of metacognitive strategies.

It is evident that each cycle includes a review and expansion of prior knowledge, along with the introduction of new knowledge. This structure allows learners to deepen their understanding of a subject while gradually building and expanding their knowledge system.

5. Learning model

A learning model is a theoretical framework for describing and guiding the learning process. In the learning model of this study, it involves a three-stage learning process of knowledge, cognitive strategies, and metacognitive strategies. The GRR (Gradual Release of Responsibility) model is used to give students more responsibility and autonomy, and the spiral structure organizes learning content and activities into a series of cycles that gradually increase in complexity.

6. Learning transfer ability

Learning transfer ability refers to the capacity of a learner to apply knowledge, and strategies acquired in one context to new situations or problems.

Learning transfer ability in this study refers to two aspects:

1) The ability to apply knowledge and strategies from learning A to solve problems;

2) The performance in learning B after learning A(Pre-study Task Test).

Students use their acquired knowledge, strategies and experience to better adapt to new situations, promoting learning or problem-solving. Here,

1) The transfer of knowledge.

2) The transfer of strategies mainly refers to the transfer of metacognitive strategies as a general skill.

3) The transfer of experience involves more frequent and successful application cognitive strategies.

7. Spiral GRR Learning model

Spiral GRR (Gradual Release of Responsibility) is an learning model that employs a spiral learning structure, which consists of three levels of learning content: knowledge acquisition, strategic learning, and metacognitive strategic learning. Within each layer, the primary teaching method is to gradually transfer the cognitive load of learning and strategy from the teacher to the student. This approach aims to foster the development of students' knowledge, cognitive strategies, and metacognitive strategies, ultimately enabling them to become learners capable of transferring their learning to new contexts.

1.7 Conceptual Framework

Conceptual framework of this study is as follows:

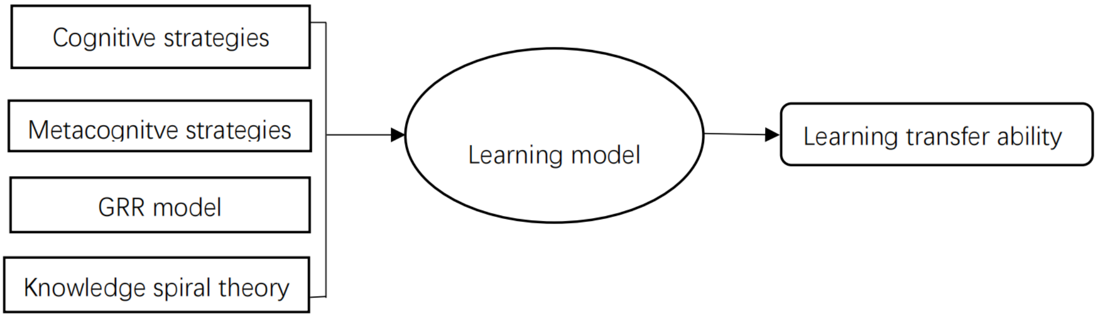

Figure 1 Conceptual Framework

A learning model will be developed based on cognitive strategies, metacognitive strategies, GRR model, and knowledge spiral theory, and then the learning model guides the students' learning process, followed by an evaluation of learning transfer ability.

CHAPTER 2
LITERATURE REVIEW

The objective of this chapter is to give a theoretical foundation, as well as review the previous study that supports the research in this paper. This chapter includes the following content that the researcher has studied

2.1 Transfer of learning

2.1.1 Definition and contents of transfer of learning

2.1.2 Process of learning transfer

2.1.3 Types of learning transfer

2.1.4 Method to achieve transfer

2.2 Cognitive and metacognitive strategies

2.2.1 Cognition and metacognition

2.2.2 Overview of cognitive and metacognitive strategies

2.2.3 The impact of cognitive and metacognitive strategies on transfer

2.3 GRR model

2.3.1 Overview of GRR model

2.3.2 The impact of GRR model on transfer of learning

2.4 Knowledge spiral theory

2.4.1 Definition of knowledge spiral theory

2.4.2 Application of spiral structure

2.5 Constructivism Theory

2.5.1 Definition of Constructivism Theory

2.5.2 Characteristics of Constructivism Theory

2.5.3 Application of Constructivism theory integrated with GRR in learning transfer

2.1 Transfer of learning

2.1.1 Definition and contents of transfer of learning

Transfer of learning has been a long-researched topic in educational psychology since Thorndike proposed his theory of identical elements in the early 1900s (Singley & Anderson, 1989; Thorndike & Woodworth, 1901). Transfer of learning can be defined as "prior learning affecting new learning or performance" (Marini & Genereux, 1995, p. 2; 2013), and is a form of higher-order thinking(An, 2014; Brookhart, 2010; Cheng & Wei, 2021; Ma & Yang, 2022; Williams, 2003; Zhang, 2010). Transfer of learning occurs when learning in one context or with one set of materials impacts on performance in another context or with other related materials(Salomon,1999). From the perspective of the learner, transfer of learning involves the active learner striving to make connections between previous knowledge and new input (Macaulay & Cree, 1999). Loebato (2003) noted that learning and transferring to different times/places are conceptually distinguishable. She observed that learners can generalize what they have learned in the classroom to situations without any new learning occurring. This would constitute successful transfer. Therefore, transfer of learning can be defined by the following two processes:

Table 1 Transfer of Learning

	Stage 1	Stage 2
1	Learning A	Applying A to solving problem
2	Learning A	Learning B

One of the key research issues in transfer of learning is "what to transfer," which refers to the content of the transfer(Pan & Yang, 2009).Transfer is often applied in the field of training and education for life and work, where the content of transfer includes

1) knowledge,

2) attitudes

3) behavior (Baldwin & Ford, 1988),or skills (Blume, Ford, Baldwin, & Huang, 2010; Grossman & Salas, 2011; Hilton & Pellegrino, 2013; Subedi, 2004).

In adult education, learning transfer emphasizes the transfer of knowledge bases and general competencies, which involves generating knowledge and information through education, as well as the capacity to learn by analogy. Vocational training focuses more on the transfer of specific competencies (which may include some general extensions), involving the explicit or implicit use of learned knowledge, skills, and attitudes in the workplace(Subedi, 2004). In learning specific course, transfer is equivalent to the transfer of knowledge(Gururajan & Fink, 2010; Hansen, 2008; Nelms & Dively, 2007).

Metacognitive strategies themselves are task-general and can be transferred to new environments and tasks (e.g., Veenman and Verheij, 2003; Schuster et al., 2020). Reflecting on the learning process and the application of strategies in a new environment. Metacognitive strategies ensure that learners apply cognitive or motivational regulation strategies with high quality (e.g., Leopold and Leutner, 2015), that is, the acquisition and transfer of metacognitive strategies make cognitive strategies more appropriately and successfully applied. Since strategies have been mentioned in previous research as task-specific and limited in transfer (Schuster et al., 2020), in this study, we refer to this as the transfer of strategic application experience.

Table 2 Content of Transfer of Learning

Transfer of learning	Transfer of knowledge
	Transfer of metacognitive strategies
	Transfer of experience in using cognitive strategies

2.1.2 Process of learning transfer

From the late 19th century to the early 20th century, psychologists began conducting empirical research and provided different interpretations of transfer phenomena, resulting in representative views such as the theory of identical elements, generalization, and relationship transformation(Li, 2022). Cognitive psychology studies transfer of learning from the perspective of cognitive structure, with representative viewpoints including cognitive structure transfer theory, production transfer theory, and cognitive strategy transfer theory(Zhao, 2022)

Identical element theory: Thorndike believed that learning forms a connection between situation and response, the transfer of learning is the transfer of the identical connection. The theory emphasizes that learning materials have identical elements in order to generate transfer(Perkins & Salomon, 1992). The more identical elements there are in both cases, the more likely it is to occur. Using the identical elements as the only means to ensure transfer in the field of education(Yang & Zhang, 2000).

The theory of insight learning: The theory of insight learning was first identified and studied by Wolfgang Köhler during his work with chimpanzees. Köhler observed that these animals were capable of problem-solving through sudden realizations, which he defined as "the awareness of functional relationships in a given situation and its rapid application to formulate a solution to the present situation"(Vonk, Vincent, & O'Connor, 2021). His experiments involved presenting chimpanzees with various problem-solving scenarios and observing their attempts to find solutions, which often included a period of incubation followed by a sudden insight(Shrestha, 2017). Insight learning, also known as "Gestalt learning," emphasizes the importance of perceiving the whole situation and understanding the relationships between elements, leading to a sudden solution or "A-ha" moment. This theory stands in contrast to behaviorist theories of learning, which focus on stimulus-response conditioning and gradual learning through trial and error(Shrestha, 2017). The concept of insight learning has evolved over time, with various theories attempting to explain the underlying mechanisms. Some of the key features of insight learning include its sudden nature, the restructuring of problem-solving strategies, and the experience of "aha" moments, which are often accompanied by a sense of satisfaction or excitement(Kizilirmak et al., 2021; Lind &

Enqvist, 2012; Osuna-Mascaró & Auersperg, 2021; Salmon-Mordekovich & Leikin, 2023). In summary, the theory of insight learning is rooted in the work of Wolfgang Köhler and has been further developed by various psychologists to explain how individuals can experience sudden understanding or solutions to problems through a process of restructuring and reorganization of knowledge and perceptions.

Both the theory of identical elements and the theory of relational transformation emphasize correlation between elements and between individual's experiences. Only by creating connections can transfer be possible.

Generalization, American psychologist Judd conducted the "underwater target shooting" experiment and believed that all experiences form a complete ideological system, forming a summary of experiences or general principles summarized from experiences that can be transferred to solve new problems(Cited in Li, 2022). The generalization theory suggests that the occurrence of transfer does not lie in the surface similarity between tasks, but in the subject's acquisition of a generalized understanding of knowledge, emphasizing the subject's transfer of learning outcomes(Li & Zhu, 2001). But what is generalized and classified is also a identical elements, just an abstract elements, that is, a general principle(Yang & Zhang, 2000). Later, Herdickson et al. (2017) further pointed out that generalization is not an automatic process, and it is closely related to teaching methods. If attention is paid to how to summarize and think in teaching methods, it will increase the possibility of positive transfer. Essentially, how to generalize is the application of cognitive tools, and how to think refers to metacognitive.

In summary, there are many commonalities among the laws reflected in different transfer theories: all transfers involve training or teaching; For any transfer, learners must form something intrinsic based on understanding as the internal condition for transfer; All transfer tasks have a certain degree of connection.

In this study, drawing on the generalization theory, it is believed that students need to learn cognitive and metacognitive skills and apply them to process and understand knowledge, and then abstract general principles, that are identical elements; drawing on the relationship transformation theory, it is believed that transfer is achieved when individuals recognize the connection between two learning experiences; drawing on the identical elements theory, it is believed that there should be similarities between the two cases when design learning materials.

In addition, it was found that the cognitive structure transfer theory is more suitable for explaining the transfer of declarative knowledge(Li, 2022). Ausubel believes that the cognitive structure of individuals, that is, the knowledge structure in students' minds, is the most important factor affecting meaningful transfer of learning(Ausubel, 1963). Declarative knowledge is represented and stored in the form of propositional networks in the human brain, and its hierarchical structure directly affects the acquisition of new knowledge(Zhu, 1999). The features of individual cognitive structure in terms of content and organization are known as variables of cognitive structure(Li, 2013), which are the abstraction and generalization of concepts, the systematicity, stability and clarity, and they are internal conditions that affect the transfer between new and old activities(Li, 2022). The latest experience gained from learning task A does not directly interact with task B, but indirectly affects B by influencing relevant features of cognitive structure. The more consolidated the original cognitive structure and the more tightly organized the hierarchical structure of knowledge, helps to promote new learning(Ausubel, Novak, & Hanesian, 1978). Ausubel (1978)believes that "teaching for transfer" is actually a problem of shaping students' good cognitive structure.

Anderson, a psychologist in information processing, proposed the theory of production transfer(Yang & Zhang, 2000). This is the development of Anderson (1990)'s Adaptive Character of Thought (ACT) theory. This theory focuses on the transfer mechanism of procedural knowledge, which requires learners to repeatedly master the program operation steps of their skills. According to the "ACT" theory, skill learning is divided into two stages: first, rules enter the learner's propositional network in the form of declarative knowledge, and then are transformed into procedural knowledge represented by production through variant exercises. The so-called production is the rules related to conditions and actions, abbreviated as the C-A rule. Production rules are identical elements between two learning tasks, so the degree of overlap in production between skills determines the degree of transfer of skills. The more overlap, the greater the transfer amount(Zhu, 1999).

The successful transfer of cognitive strategies refers to the ability of problem solvers to determine the requirements of new problems, choose special or general skills that were previously acquired and applicable to new problems, and monitor their application when solving new problems. Here, the problem-solver is an active participant and must manage the application of existing knowledge used to solve new problems. Not only does one need to learn the specific process and usage method of a certain strategy, but they also need to understand the scope of application of the strategy, be able to monitor the process of using the strategy, and modify their own strategy when necessary, so that the strategy they have learned can truly achieve transfer(Zhu, 1999). An important condition for cognitive strategies to reach a transferable level is the learner's level of reflective cognition(Detterman & Sternberg, 1993), that is, their metacognitive level(Guo, 2005).

The development of metacognitive levels is contingent upon the learning of metacognitive strategies. Given that previous researches have highlighted cognitive strategies as being task-specific and limited in their transferability(Schuster et al., 2020), this study does not define the transfer of cognitive strategies. On one hand, the learning of metacognitive strategies ensures that learners apply cognitive or motivational regulation strategies with high quality(e.g., Leopold and Leutner, 2015). This implies that the acquisition and transfer of metacognitive strategies enable cognitive strategies to be applied more appropriately and successfully. We term this the transfer of experience in strategy application. On the other hand, metacognitive strategies, being task-general, can be transferred to new environments and tasks(e.g.,Veenman and Verheij, 2003; Schuster et al., 2020), demonstrating a high level of metacognition. Based on these, When learners face different learning tasks, they can effectively utilize the general laws of transfer of learning and different mechanisms, principles, and strategies.

2.1.3 Types of learning transfer

Researchers conducted a comparative analysis of the types of learning transfer in their research(Bardovi-Harlig & Sprouse, 2018; Fishman, Reiff, & Smit, 2015; Kassai, Futo, Demetrovics, & Takacs, 2019; Perkins & Salomon, 1992), with the main content as follows.

Table 3 Types of Transfer

Type Name	Description
Positive Transfer	Learning in one context enhances performance in another context.
Negative Transfer	Learning in one context negatively affects performance in another context.
Near Transfer	Transfer between contexts that are very similar.
Far Transfer	Transfer between contexts that appear to be distant and unfamiliar on the surface.
Reflexive or Low Road Transfer	Transfer of well-practiced routines triggered by the stimulus conditions in the learning context.
Mindful or High Road Transfer	Transfer involving a process of deliberate effort, abstraction, and seeking connections.

Under the pressure of improving students' standardized test scores, teachers sometimes teach to the test - this is an example of applying a near transfer teaching strategy (Larsen-Freeman, 2013). In this study, due to the lack of long-term follow-up and only a one-semester teaching period with testing, it only involves near transfer.

2.1.4 Method to achieve transfer

Transfer of learning is a key concept in adult learning theories because most education and training aim to achieve learning transfer. Transfer does not occur automatically; it is a process that requires the implementation of carefully planned strategies to facilitate it(Subedi, 2004).

To achieve learning transfer, Salomon (1999) summarized the research results of other scholars on the occurrence of transfer and emphasized that there are five conditions for transfer. 1) Thorough and diverse practice; 2) Explicit abstraction. The study by Gick and Holyoak (1983) suggests that clarifying abstract principles from a situation can aid in transfer; 3) Active self-monitoring, also known as metacognitive reflection, seems to promote skill transfer through self-monitoring of one's own thinking processes. Belmont, Ferretti and Mitchell (1982)conducted a study on memory strategy transfer in mentally disabled children. The results seem to indicate that children who successfully transfer memory strategies not only apply the strategies, but also monitor their thinking processes in a simple way; 4) Arousing mindfulness. Mindfulness refers to a general state of alertness towards one's activities and surrounding situation; 5) Using a metaphor or analogy. Students can better understand new objects and promote transfer by applying analogies or metaphors.

The factors that affect learning transfer are numerous and complex. Cree and Macaulay (2000)pointed out that learning transfer is a complex process in which individuals consciously and subconsciously connect previous experiences with new situations to understand the world. It is influenced by a series of factors, including the specific characteristics of learners, learning and transfer tasks, and situations. Tyson, Venville, Harrison and Treagust (1997) studied the factors of transfer from the perspective of different situations, advocating to solve transfer problems by limiting situations, and believing that good learning situations are conducive to the occurence of transfer. Langer (1993)argue that individual characteristics such as willpower, curiosity, and motivation for learning Play an important role in transfer. Demirer & Sahin (2013) conducted a 14 week pre-test and post-test experimental study on the transfer of students' theoretical knowledge into their educational multimedia projects, and concluded that blended learning methods have a positive effect on learning transfer. Chinese scholars' research on the factors that affect learning transfer is mainly reflected at the individual level and the external environment level. From a individual perspective, it mainly includes cognitive level, generalization ability, cognitive strategies and skills, and learning motivation. Nie (2009) proposed the impact of cognitive strategies and generalization ability on students' learning transfer through case analysis. Ding (1996) proposed the impact of students' cognitive structure on learning transfer by analyzing the three variable characteristics of cognitive structure. Wang and Feng (2009) proposed that cognitive strategies can affect learning transfer in English teaching. Zhao, Li and Liu (2019) proposed that the motivation of online learning has a significant positive impact on learning transfer from the perspective of adult online learning. In addition to individual factors, the impact of external environment on learning transfer cannot be ignored, such as learning materials, teaching organization and design, and learning situation. Ren (1996) used algebraic operation materials to explore the factors that affect learning transfer, and concluded that the similarity of learning materials is an important factor affecting transfer. Yang and Niu (2003) proposed that the key to the development of learning transfer lies in exploring identical elements between learning materials, striving to create prerequisites for learning transfer, and promoting the occurrence of learning transfer. Qu (2006) studied the factors that affect learning transfer from the perspective of situational learning theory, explored the mechanism of situational factors on transfer, and pointed out that situational factors promote transfer by combining with other factors. Wang (2005) studied the impact of situational cognition on learning transfer ability, emphasizing the relationship among learning transfer, individuals and the environment.

The research on the cultivation of learning transfer ability is mainly reflected in the exploration of combining with specific disciplines, but there is still little research on the learning transfer in Econometrics. Wang (2003) takes the biology as an example and proposes to search for overlap and correlation between knowledge and compares the characteristics of new and old knowledge, which helps students build a knowledge system and cultivate their learning transfer ability. Qu (2016) believes that the cultivation of transfer ability should improve students' generalization ability. Dyre, Tabor, Ringsted and Tolsgaard (2017)conducted error management and error avoidance training for medical students without ultrasound experience. After training, transfer tests were conducted. The results showed that providing error management guidance in simulation training can improve the transfer of learning to the clinical situation compared to error avoidance guidance. That is, if trainees are encouraged to make mistakes, the transfer of learning may be improved. Klauer (1989) researched on problem-solving, inductive thinking, and learning to learn and had shown that by teaching basic structures, the basic structure obtained from one or more instances can be transferred to another instance in various fields and situations. Meng (2011)emphasized that the process of applying knowledge can promote transfer. Some scholars have also proposed the cultivation of transfer ability between disciplines(Darbellay, 2015; Delogu, Lampis, & Olivetti Belardinelli, 2006)

In summary, the importance of transfer is reflected. Researchers have proposed some specific "transfer teaching" strategies. For example, a sufficient level of original learning, learning with understanding, using specific examples of learning and transfer, requiring students to create solutions to a large class of problems, and representing problems and solutions with appropriate levels of abstraction and metacognition can promote effective and positive transfer (Bransford & Schwartz, 1999; Macaulay & Cree, 1999; Nelms & Dively, 2007). Dewitz and Graves (2014)pointed out that 'there will definitely be some negative transfers, but we can minimize them by carefully designing students' transfer tasks.' For example, informing students of exceptions to certain rules and providing examples of exceptions.

Table 4 Method of Achieving Transfer of Learning

Specialist	method	Develop learning model principles
Harrison et al., (2017)	a hybrid-flipped model of learning	Student-centered
Hung, (2013)	Problem-based learning	Case or application problem
Van Merriënboer, Kester & Paas(2006)	Balancing intrinsic and germane load: high variability and limited guidance or feedback	Provide scofford By GRR model
Leberman & Martin(2004)	post-course reflection	metacognition
Carpenter(2012)	Testing	test
Kalyuga(2013)	generalized domain knowledge structures	cognition
Brooks(2022); Wu, Lee & Shu (2013)	using Nonaka and Takeuchi (2007) Knowledge Spiral Theory, employing a spiral curriculum approach	Spiral structure

2.2 Cognitive and metacognitive strategies

2.2.1 Cognition and metacognition

Cognition refers to the mental processes involved in acquiring, processing, storing, and utilizing information. This encompasses a broad range of cognitive functions such as perception, attention, memory, reasoning, and language (Miller, 2003). Cognitive psychology, which is the study of these mental processes, seeks to understand how individuals interpret and interact with the world around them based on these cognitive functions.

In cognitive science, cognition is often likened to an information processing system, akin to how computers process data. This system comprises various subsystems that manage different aspects of information processing. For instance, the perceptual system is responsible for receiving and interpreting sensory input, the memory system handles the storage and retrieval of information, and the executive system oversees planning and decision-making(Anderson, 2007). The interaction between these subsystems determines how individuals understand and respond to their environment.

Cognition extends beyond the realm of psychology to include fields such as neuroscience, philosophy, and artificial intelligence. In neuroscience, researchers investigate how brain structures and functions underpin cognitive processes (Gazzaniga, 2018).

Bloom divided the cultivation of cognition into six levels from low to high: memorization, understanding, application, analysis and synthesis, and evaluation(Bloom, Krathwohl, & Masia, 1964).

Human cognition is a reflection of objective things and also a spiral development. Lenin said, Human cognition is not a straight line, but infinitely approximates a series of circles and a spiral curve(Lenin, 1969).

Metacognition refers to an individual's cognition of the process of self-awareness, as well as the self supervision, planning, and regulation based on this cognition(Flavell, 1979). One of the important mechanisms of metacognition is to regulate individuals to make adaptive strategic choices, thereby completing behaviors and achieving goals(Liu, Si, & Wang, 2011).

Metacognition can enable learners to understand why, how, when, and where these strategies can be used, and how to evaluate them, enabling learner to better transfer strategies in different situations(Brown, Hedberg, & Harper, 1994).

The most effective metacognitive teaching methods include providing learners with knowledge of cognitive processes and strategies, as well as experience or practice in using cognitive and metacognitive strategies(Livingston, 2003).

2.2.2 Overview of cognitive and metacognitive strategies

Educational psychologists have conducted extensive research, detailing how cognitive strategies develop and how the development of these strategies can improve students' performance in key learning tasks. Cognitive strategies are the means to achieve cognitive goals (such as understanding or memory), involving underlying conscious and controllable activities (Pressley & Harris, 2009). Cognitive learning strategies include review strategies, organizational strategies, and elaborative processing strategies (Weinstein, Husman & Dierking, 2000). cognitive strategy knowledge refers to general methods of learning, memorizing, or solving problems(Zhao, Liu, & Zhang, 2003). Strategies are important processing objects of metacognition, and the regulation of strategy selection is one of the important mechanisms of metacognition(Desoete & Roeyers, 2002; Verschaffel, Luwel, Torbeyns, & Van Dooren, 2009). Obergriesser and Stoeger (2020)explored how students' emotions of enjoyment and boredom affect their use of cognitive learning strategies, and vice versa. In discussing the impact of emotions on the selection and application of learning strategies, the study mentioned review strategies, organizational strategies, and elaborative processing strategies, and emphasized the role of goal setting or monitoring in student learning.

A related and equally important aspect of metacognition is knowing when and where to use specific cognitive strategies, sometimes referred to as conditional knowledge(Paris, Lipson & Wixson, 1983). Students who struggle academically may not activate strategies, but if reminded that they are an appropriate method for solving specific problems, they can employ these strategies. The difference between effective and ineffective performance is often partly attributed to metacognitive understanding—that is, knowing when and where to apply known strategies(Pressley & Harris, 2009).

Schneider & Artelt (2010) discussed the components of metacognition and emphasized the distinction between declarative metacognitive knowledge and procedural metacognitive knowledge. Declarative metacognitive knowledge involves understanding specific tasks or learning situations, including their requirements, difficulty, complexity, and the time or resources needed to complete them. It also involves knowing which learning or cognitive strategies are most effective for specific tasks. For example, knowing that reviewing notes is more effective for memorization than simply reading textbooks is declarative metacognitive knowledge about strategies. In contrast, procedural metacognitive knowledge focuses on the "knowing how to do" aspect, covering self-monitoring and self-regulation skills used in cognitive activities. These skills are procedural, involving the application of metacognitive knowledge to guide and adjust behavior in actual cognitive tasks. Metacognition enables individuals to make adaptive strategic choices, thereby completing behaviors and achieving goals, and the influence of metacognitive knowledge is likely to be latent and interacts with various other factors in the overall cognitive system to affect learning(Liu et al., 2011). The research by Liu et al. (2011) emphasizes that students also need to have the knowledge of why strategies are effective. Whether the selection of strategies is successfully completed largely depends on whether learners know under what conditions to use a certain strategy, and how to use the strategy to complete new tasks, which is metacognitive knowledge. The most effective metacognitive teaching methods include providing learners with knowledge of cognitive processes and strategies, as well as experience or practice in using cognitive and metacognitive strategies(Livingston, 2003). Flavell (1979) proposed that metacognition consists of both metacognitive knowledge and metacognitive experiences or regulation.

Research indicates that even if information is accessible to individuals, it does not necessarily mean it will be utilized. In other words, even if knowledge is available, learners may not utilize declarative or procedural knowledge (Fayol, 1994). Therefore, a complete learning process includes three stages: acquisition of declarative knowledge, acquisition of procedural knowledge, and the application of knowledge to solve problems.

2.2.3 The impact of cognitive and metacognitive strategies on transfer

Some studies have shown that the application of cognitive and metacognitive learning strategies can effectively improve students' performance(Abdul Aziz, 2016; Akpur, 2021; Aravind & Rajasekaran, 2020; De Boer, Donker, Kostons, & Van der Werf, 2018). IMPROVE (a powerful mathematics instructional method), as a metacognitive teaching approach, holds the potential to improve procedural knowledge, conceptual knowledge, and metacognition, which are critical these factors in students' academic achievement. The focus of this study is to investigate whether declarative and procedural knowledge acquired in econometrics, along with cognitive and metacognitive strategies, can enhance students' academic performance and transfer of learning.

Researches has shown that cognitive strategies and metacognitive strategies can improve students' performance and achievement (Saied & Mehrabi, 2013; Yang, 2005; Fooladvand, Yarmohammadian & Zirakbash, 2017). Belmont, Butterfield, and Ferretti (1982) encouraged students to monitor whether the use of strategies improved their performance (for example, by asking themselves, "Did the plan work?"). Özkubat & Özmen (2021) used tools such as think-aloud protocols and metacognitive experience questionnaires in their research and found a correlation between students' problem-solving performance and metacognitive strategies. Moreover, if people understand that a strategy has a positive impact on their performance, they are more likely to continue using that strategy (Pressley, Borkowski, & O'Sullivan, 1985). Metacognitive skills help students become more proficient in focusing on key elements of a problem, connecting or abstracting identical themes from previous problem-solving events or learning experiences, and evaluating their progress in finding the good solution for well-structured or ill-structured problems(Bransford, 1999; Sutton, 2003).

This passage discusses the relationship between strategy learning and transfer of learning. From the above, strategy learning improves learning performance. Better learning achievement is conducive to transfer of knowledge(Pham & Huynh, 2018). Because good academic performance indicates a good understanding of knowledge, the ability to generalize identical elements, and thus transfer them effectively; Metacognitive strategies serve to regulate cognitive or motivational strategies within a wide range of learning tasks, and research has demonstrated that metacognitive skills can enhance performance across multiple domains(e.g., Carretti et al., 2014; Ohtani and Hisasaka, 2018; Zepeda et al., 2019). So, metacognitive skills are task-general(e.g., Veenman and Verheij, 2003; Schuster et al., 2020) and once learned, it can be transferred to new contexts and tasks; Cognitive strategies are task-specific because they directly address the particular kinds of information processing that must be adapted to a specific learning tasks (Weinstein et al., 2000). Therefore, their transferability is limited(Schuster et al. 2020). However, the learning of metacognitive strategies ensures that learners understand the scope of application of the strategy, be able to monitor the process of using the strategy, and modify their own strategy when necessary so that the strategy they have learned can truly achieve transfer(Zhu, 1999)-that is the transfer of experience in strategy application in this study. So, in this study, transfer of learning includes transfer of knowledge, metacognitive strategies and experience in strategy application.

2.3 GRR model

2.3.1 Overview of GRR model

GRR means the gradual release of responsibility, which appeared between 1978 and 1983. To some extent, it is driven by Durkin's (1978/1979) astonishing insights into classroom reading comprehension teaching. Effective reading comprehension cannot be achieved without the reader's metacognition. To become a good reader with a high level of reading comprehension, metacognitive strategies must be used to regulate it(Yang, 2011).

In the early 1980s, the classic GRR visual model was born. Pearson was inspired by Joe Campione's responsibility pie and the classic gun and butter production function curve, conceptualizing the completion of comprehension tasks into various combinations of responsibility between student and teacher. He drew the teacher's responsibility on the y-axis and the student's responsibility on the x-axis, the more teachers do, the less students do, and vice versa (see Fig. 3) (Pearson, McVee, & Shanahan, 2019). In 1983, the original version of the GRR model was published (see Fig. 4). Afterwards, with the efforts of researchers, the GRR model was gradually developed an updated version by Duke, Pearson, Strachan, and Billman(Duke & Pearson, 2009; Duke, Pearson, Strachan, & Billman, 2011),see Fig 5.

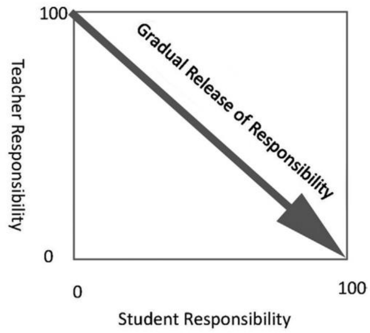

Figure 2 The "Gradual Release of Responsibility"

Source: Pearson et al. (2019). In The Beginning: the Historical and Conceptual Genesis of the Gradual Release of Responsibility p.6.

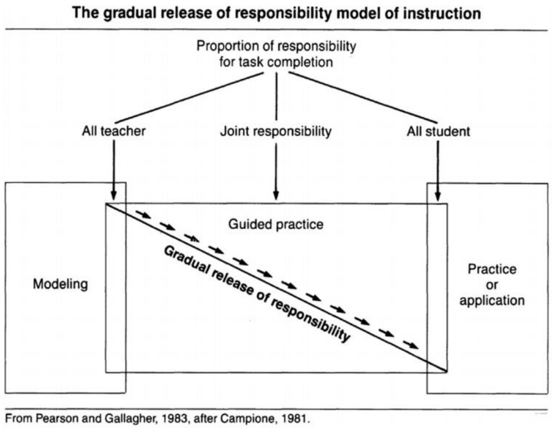

Figure 3 The Original Published Version of the GRR Model in Contemporary Educational Psychology in 1983.

Source: Pearson et la.(2019). In The Beginning: the Historical and Conceptual Genesis of the Gradual Release of Responsibility p.7.

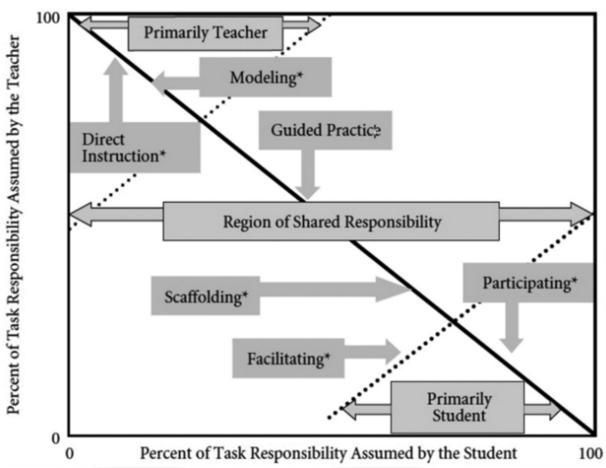

Figure 4 The Model as Depicted by Duke and Pearson (2002).

Source: Raphael & Au (1998). The Gradual Release of Responsibility p. 9.

GRR means that “when the content is new and unfamiliar, the cognitive responsibility is primarily the teacher’s. As the learner acquires knowledge, the intellectual weight shifts”(Fisher & Frey, 2013, p.1). GRR shifts teachers' cognitive load to students, especially metacognitive awareness (Fisher & Frey, 2021). GRR model teaches how to understand. Understanding requires the cognitive subject to use various cognitive and metacognitive strategies based on existing knowledge and experience(Wei & Zou, 2003).

The sequential steps of the GRR model do not necessarily mean that teachers must always start with modeling, then guiding practice, and finally independent practice. Teachers can start a sequence by asking students to "try it out on their own" and provide feedback and assistance when students show a need. In this way, the model is flexible(Pearson et al., 2019). In fact, understanding is a complex brain processing process that cannot be simply divided into several simplified discrete skills. Therefore, classroom teaching requires flexible responses rather than strict adherence to formats or procedures(Duffy, 2014). Teaching usually balances the teaching of teachers with the learning of students, making their learning "visible". The focus of the classroom has shifted from "focusing on changes in students' surface states" to "focusing on changes in students' deep cognitive and understanding states"(Webb, Massey, Goggans & Flajole, 2019).

One of the most widely disseminated adaptations of GRR is from D. Fisher, N. Fisher, and Frey (2014), where cognitive responsibilities are measured by the relative space allocated to teachers and students in the "I do", "We do", and "You do" areas(see,Fig 6).

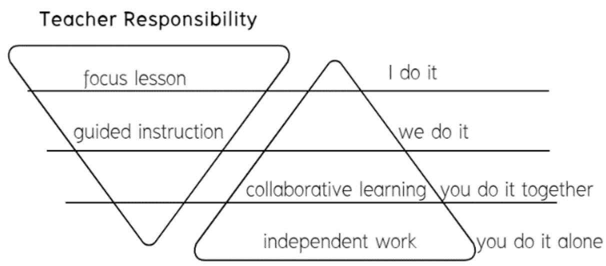

Figure 5 Fisher and Frey's Version of the GRR Model.

Source: Pearson et la.(2019). In The Beginning: the Historical and Conceptual Genesis of the Gradual Release of Responsibility p.14.

Due to its effectiveness to gradually transfer cognitive responsibilities in frontline practice, GRR has been promoted by the American Society for Visual Guidance and

Curriculum Development (ASCD), and this teaching program has gradually become a stable teaching model.

According to D. Fisher, N. Fisher and Frey (2014), there are four parts in the GRR classroom:

1. Focused instruction: The teacher shows students their thinking and understanding of the content, presenting or demonstrating their own "expert knowledge", or providing students with learning objectives and opportunities to establish and activate background knowledge. “The key to a quality focus lesson is explaining. …,students need an explanation of their teachers' cognitive and metacognitive processes "(P.19)

The focused instruction is a manifestation of responsibility, and the three most commonly used methods in this stage are modeling, metacognitive awareness, and aloud thinking. These three technologies have different uses. Modeling emphasizes cognition, that is, how to complete skills, tasks, or strategies; Metacognition extends cognition by monitoring the use of learned content, meaning that students are not only taught how to do something, but also analyze whether their use of learned knowledge is successful; Aloud thinking is a combination of cognition and metacognition, where the teacher shares how he or she uses both to understand the content.

In this section, teachers externalize the "thinking process" through forms such as "explanation, demonstration, and aloud thinking".

2. Guided instruction: It is the key to transferring cognitive load and classroom responsibility to students. The dialogue between teachers and learners is carefully crafted according to the principles of scaffolding. Scaffolding is a temporary support provided by a teacher to a learner (in the form of questions, clues, and prompts) to help him or her transition to skills or concepts that he or she cannot independently complete or understand(Wood, Bruner, & Ross, 1976). Students are the leaders of learning, and the role of teachers is to respond to subtle clues that indicate

understanding and misunderstanding. In fact, effective scaffolding requires teachers to have professional knowledge of the clues.

The guiding question that teachers often ask themselves is "What does his answer tell me about what he knows and what he doesn't know?" Then they make assumptions about what students know and provide timely responses. Thus guiding students to correctly understand, recognize, and apply.

3. Collaborative learning: It is important to organize mixed ability groups purposefully by teachers, and success in collaborative groups depends on whether students have the opportunity to interact with peers with different ideas, interests, and skills(Sapon-Shevin, 2007). A study on group work with similar abilities found that homogeneous groups cannot collaborate effectively e.g.(Bennett & Cass, 1989); Webb (1982). Bennett and Cass's (1988) study found that when the number of low scoring students exceeds the number of top students in the constructed heterogeneous population, they will be more successful. Compared with more traditional individualized and competitive models of learning, students who learn in cooperative groups exhibit markedly improved individual achievement, metacognitive thought, willingness to assume difficult tasks, persistence, motivation, and transfer of learning to new situations(Johnson, Johnson, & Smith, 1991; Prince, 2004).

Student groups can use four understand strategies: summarizing, question generating, clarifying, and predicting. Summarizing refers to cognitive strategies. Clarification is a metacognitive activity in which students clarify the parts that hinder their understanding.

4. Independent learning: At this stage, students begin to independently apply skills to specific situations for learning and problem-solving. This is also the ultimate goal of classroom teaching.

The implementation of GRR reflects the dynamic change process of the teaching subject in the classroom teaching process through the representation of two triangles, reverse and forward.

GRR has now become one of the most commonly used teaching frameworks in the fields of reading and literacy teaching research(Pearson et al., 2019). In addition, GRR research is also used to assist pre-service and in-service teachers or in reflecting on their teaching through videos (McVee, Shanahan, Hayden, Boyd, & Pearson, 2018; McVee et al., 2015; Shanahan et al., 2013). As the basic model for teaching comprehension strategies, GRR not only teaches students how to understand knowledge, but also how to monitor and regulate cognitive processes, and evaluate cognitive outcomes(Fisher & Frey, 2021). GRR attaches great importance to the transmission process of "metacognition" in the construction of "scaffolding", ultimately cultivating independent, competent, and confident learners(H. P. Wu, 2020). This study attempts to use GRR developing students' knowledge cognitive and metacognitive strategies while learning knowledge in Econometrics, so that they can better develop the understand of knowledge and strategies, develop the level of metacognition, and achieve transfer of learning.

When David and Meg coined the term "gradual release of responsibility" in 1983, scaffolding was the core concept behind GRR(Pearson et al., 2019). According to Pearson et al. (2019), "Scaffolding provided a powerful label for what it is that the more knowledgeable others could and should do when working in the ZPD." (p. 5). Learning occurs in the zone of proximal development (ZPD), and if encountering the help and support of "knowledgeable others", they can help students develop from what they can accomplish themselves to what they can accomplish with the help of friends or teachers(Pearson et al., 2019). In the ZPD, guidance from knowledgeable individuals is essential(Liu & Yu, 2020), and others with more knowledge can also become peer learners(Deeney & Dozier, 2015). Scaffolding provides a label that tells more knowledgeable people when to do and what to do to help learners. As students develop greater independent control in any strategies, skills, or practices, teachers reduce the amount of time (and course) spent on scaffolding. This is the most common and transparent insight about scaffolding(Pearson et al., 2019). The reduction and withdrawal of scaffolding indicates that students gradually acquire knowledge and strategies through GRR teaching, and develop the ability to independently solve problems. Therefore, guidance from the more knowledgeable others is crucial in the application of the GRR model. In this study, the developed learning model is applied to classroom teaching, where the more knowledgeable others are primarily teachers but can also be students.

2.3.2 The impact of GRR model on transfer of learning

Many scholars unanimously believe that using the GRR model in teaching stimulates students' cognitive responsibility and cultivates their autonomous learning and exploration abilities. Hu Die (2020) explores the application strategies of GRR model in teaching English writing in elementary school. She pointed out that teachers can teach writing based on the GRR model, through "centralized guidance to guide the path of thinking; targeted guidance to discover the highlights of writing; cooperative learning to achieve the collision of ideas; independent learning to achieve wisdom generation", to achieve the transformation from "teaching" to "learning", and to cultivate students' independent writing and independent learning. Y. P. Wu (2020) explores how to provide students with scaffolding teaching based on GRR in high school information technology classrooms, guiding them to discover problems, self explore, and ultimately independently solve problems. Pan (2015) pointed out that excessive "support" in primary school art teaching is not conducive to children's individuality and independent creation, and can easily stifle children's creativity. Therefore, basic skills should be 'supported', and specific operations should be boldly 'released'. Xia (2016)based on the global learning perspective, pointed out that using the GRR model in English teaching can improve students' poor classroom performance of "passive catering" and "shallow participation", and stimulate students' "cognitive responsibility". Peng (2022) applied GRR to the cultivation of middle school students' English writing ability, ensuring that students participate in learning activities in a meaningful way and achieve learning goals under the guidance of classroom objectives. As Buehl (2005) stated, the GRR model “emphasizes instruction that mentors students into becoming capable thinkers and learners when handling the tasks with which they have not yet developed expertise”.

Some scholars have conducted teaching practices, indicating that the use of GRR model has promoted students' learning transfer. Wu et al. (2018)used the GRR model to design teaching in response to issues such as uneven cognitive levels, limited classroom forms, and so on, in existing computer basic course teaching. The results indicate that using the GRR model to construct a conceptual framework for "metacognition" is beneficial for students to engage in meaningful learning. (Xu, 2022) adopted a "combination of support and release" approach in the design of high school geometry teaching based on mathematical culture. He emphasize the importance of teachers guiding students' thinking changes, allowing students to experience the formation, development, and application of knowledge through problem-solving in the situation, and updating their cognitive structure. Zhou and Sheng (2021) pointed out that the "supporting and releasing with a certain degree" teaching model focuses on the changes in the focus of classroom teaching activities on "teachers providing guidance" and "students actively participating". As the activity progresses, the supportive role of teachers needs to be continuously reduced, and the participation of learners in the activity gradually strengthens. They emphasize that only in this way can learners freely solve complex new learning tasks and real-life situations in order to achieve their ultimate goal. Pang (1999) pointed out that cultivating autonomous learners not only requires imparting students various general and domain specific learning strategies, but also specifying the conditions and scope of strategy application to students, and letting them know that they need to make efforts to apply a large number of strategies in order to ultimately achieve strategy transfer. The implementation of the GRR model in teaching involves transferring understanding from teachers to students, including strategies, strategic regulation, and self-monitoring. TeachThought Staff (2021) stated that the goal of this GRR approach is autonomy and efficacy on the part of the student–ideally, the ability to transfer understanding on their own. Transfer of learning includes transfer of skills, knowledge, understanding or attitude, but transfer of skills, knowledge and attitude is based on understanding, so once transfer of understanding occurs, then transfer of knowledge, skills and attitude will be naturally achieved.

2.4 Knowledge spiral theory

2.4.1 Definition of knowledge spiral theory

Knowledge Spiral Theory, was developed by Ikujiro Nonaka and is a concept within the broader field of knowledge management. The theory describes the process of knowledge creation as a spiraling dynamic through which knowledge is created, shared, and advanced within an organization. The spiral signifies continuous growth and the deepening of understanding as individuals and groups engage in the conversion of tacit and explicit knowledge (Nonaka & Takeuchi, 2007).

The spiral structure underscores the significance of ongoing learning and adaptability. It encompasses the dynamic interaction of diverse knowledge forms, each spiral cycle constructing upon the previous, fostering incremental progress in knowledge acquisition(Nonaka, 1994).

The process of knowledge creation emerges through this structure, with each rotation of the spiral symbolizing the integration of novel perspectives and comprehensions into the organizational knowledge reservoir(Nonaka & Takeuchi, 2007).

Actually, in this research, the following learning process in these three rounds embodies the core concept of spiral structure which is that learning is a dynamic and iterative process. Each spiral cycle builds upon the previous one, facilitating gradual progress in knowledge acquisition. Through interaction with varies forms of knowledge, learners continuously construct, revise, and expand their understanding. Every integration of new perspectives and understandings into the knowledge reservoir. This gradual and deepening approach can facilitate learners' deep undestanding and flexible application of knowledge.

1. Learning knowledge - econometrics content

2. Learning cognitive strategies in learning knowledge - Emphasize cognitive strategies in the process of learning knowledge.

3. Learning metacognitive strategies in learning knowledge and cognitive strategies - Emphasize metacognitive strategies in the process of learning knowledge and cognitive strategies.

2.4.2 Application of spiral structure

Scholars also apply similar spiral structures to study spiral learning and spiral courses(Blankson, 2022; Bruner, 2009; Coelho & Moles, 2016; Coolidge, 1966; Diamond, Koernig, & Iqbal, 2008; Harden, 1999). According to Harden (1999), a spiral curriculum have four features: Topics are revisited; There are increasing levels of difficulty; New learning is related to previous learning; The competence of students increases. During the GRR process, students learn a understanding theme, but the difficulty increases. Through the spiral learning, it promotes students' deeper understanding and acquisition of understanding strategies.

According to McVee et al. (2015), the learning process has the essence of iteration. They study teachers' learning, teaching, and reflection, believing that the process of learning and reflection involves multiple iterations of responsibility and support for learners from more knowledgeable others, represented by a circular arrow (see Fig 9). Shanahan, Tochelli-Ward and Rinker (2019) also found that teachers conducted three rounds of iterative GRR during strategy teaching. The first round of GRR allowed teachers to transfer declarative and procedural knowledge of strategies to students. In the second and third rounds, teachers transferred conditional knowledge of strategies to students, that is, knowledge of when and why strategies were used, which is essentially metacognitive knowledge(Lai, 2011). It can be seen that the GRR iteration process sequentially shifts the cognitive load and metacognitive awareness of strategies to students.

Indeed, based on the complexity of the understanding process(Zhao, 2004), learners' learning and cognition of knowledge are not completed in one go, and their understanding of problems is a spiral upward process(Song, Li, & Wang, 2009). Constructivism believes that the process of constructing knowledge has nonlinear characteristics. Because different understandings constitute the full meaning of this thing, learners have different understandings of the same thing, and the construction of knowledge can only be achieved through mutual consultation, multiple iterations, and spiral development(Liu & Chen, 2013). In addition, due to the complexity of the knowledge structure itself, sometimes it is necessary to conduct iterations of multi-level learning processes, ultimately completing the cognition of a complex knowledge(Chen, 2014).

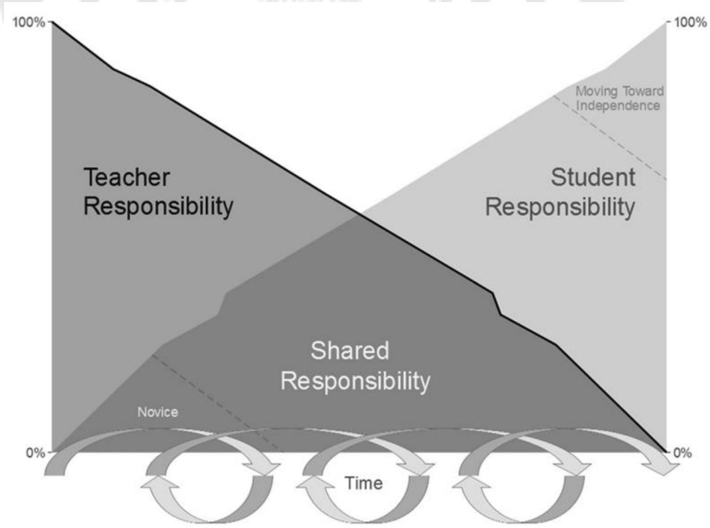

Figure 6. Responsibility from Teacher and Student in the GRR.

Source: Pearson et la.(2019). In The Beginning: the Historical and Conceptual Genesis of the Gradual Release of Responsibility p.17.

The combination of GRR and spiral shape developed spiral GRR. Traditional GRR emphasizes the sequential implementation of four stages or the flexible dismantling of four stages. Spiral GRR is a multiple cycle and iteration of four stages. In each round, different learning priorities are transferred from teachers to students, and teachers provide different scaffolding support to students compared to the previous round(Shanahan et al., 2019).

Based on the sequential nature of knowledge acquisition and the research of Shanahan et al. (2019), several rounds of iterative GRR sequentially transfer declarative knowledge, procedural knowledge (cognitive load level), and metacognitive awareness (metacognitive level) to students.

Human cognition is a reflection of objective things and also a spiral development. Lenin said, Human cognition is not a straight line, but infinitely approximates a series of circles and a spiral curve(Lenin, 1969).

Spiral theory is a theory first proposed by Bruchon in the mid-20th century. He believed that social development is not a straight line, it is not only controlled by internal and external environments, but also has its own circularity. Therefore, the "general form cycle" theory gradually formed, with spiral theory occupying the main position and better depicting the development process of society(Chen, 2001).

The development of a thing itself is the unfolding of its opposite, achieving a dialectical movement from lower to higher levels through both struggle and unity of the opposite. Its basic direction and overall trend are forward and upward, and it is a spiral or wave like process of tortuous progress(Ai, 2023). The spiral of development is a visual summary of the inevitable twists and turns in the development process of things, and a philosophical description of the forms of negation and negation of the law(Y. Q, 2017). It indicates that the development of things from simplicity to complexity, from low-level to high-level, is a dialectical process that starts from oneself, as if returning to oneself, and is enriched and improved. Each spiral reaches a higher level of degree relatively(Ai, 2023).

CHAPTER 3
METHODOLOGY

This study aim to develop a new learning model rooted in knowledge, cognitive strategies, metacognitive strategies, GRR model, and spiral structure to enchance the students' learning transfer ability, This research divided into three main phases.

Phase 1: Research basic data for definition and learning model

This stage entails examining and reviewing pertinent literature, encompassing the issue context, to establish foundational data for delineating the concept of learning transfer and the formulation of a learning model. It is bifurcated into two principal stages:

Step 1: Research the relevant literatures.

Step 2: Survey students' problem situations and teachers' opinion through interview.

Phase 2: Learning model development

This phase is to develop step of the learning model "development of a spiral GRR learning medel to enhance students' transfer of learning", using the information gathered from the phase 1.

Learning model develop steps:

This phase is to develop the "spiral GRR" learning model and give the develop steps of the learning model draft:

1. Theoretical foundation of learning model
2. Learning objectives
3. Learning contents
4. Learning process
5. Learning methods
6. Learning activities
7. Learning evaluation

Expert assessment and revision

The preliminary learning model underwent scrutiny by a panel of five specialists to validate its design, focusing on the suitability and coherence of its elements. Following the expert review, the model was refined based on their recommendations.

Phase 3: Deployment and Assessment of the Learning Model

This phase encompasses the practical application and assessment of the learning model, which involves the following elements:

1. Experimental setup.
2. Variables: the independent variable and the dependent variable.
3. Target population and sample selection.
4. Research instruments.
5. Execution of the learning model.
6. Learning model evaluation.
7. Learning model revision.

Learning model evaluation including Data collection and Data analysis, is that learning model drafts are evaluated in terms of transfer of learning, classroom performance and students' emotion on learning.

Learning model revision is that after the new learning model was implemented and evaluated, the learning model was revised again.

Leaning model development plan for this research:

The approach used for the development of the learning model has been encapsulated in Figure 7.

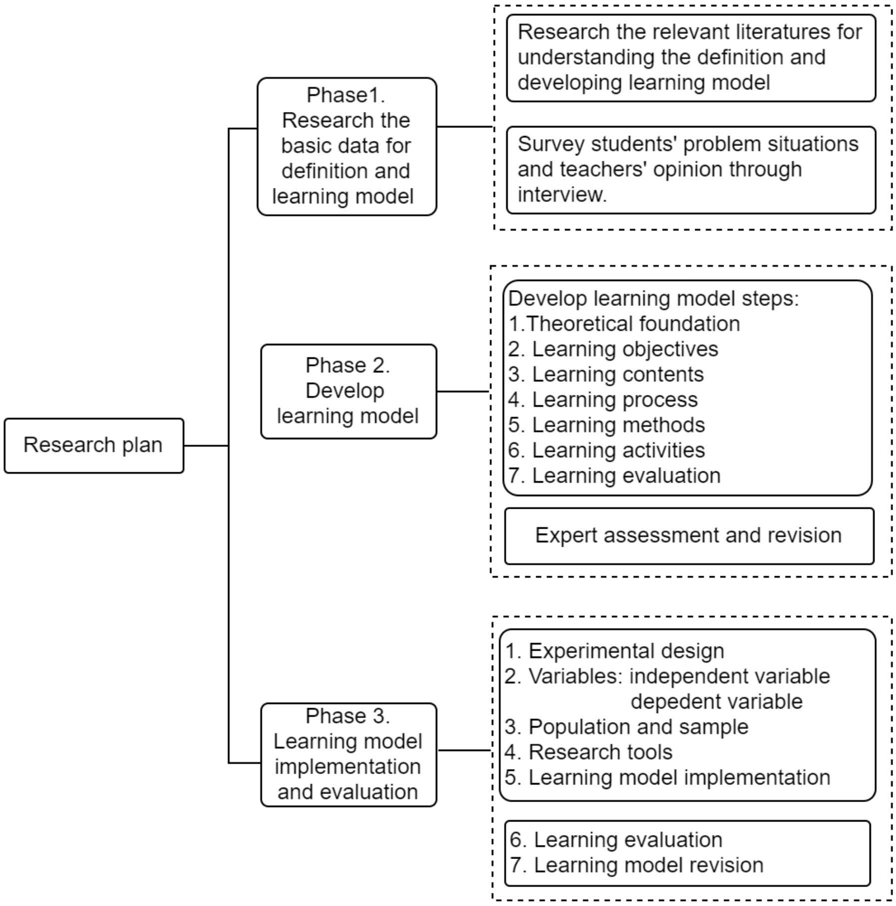

Figure 7 Research plan framework

Phase 1: Research basic data for definition and learning model

This phase is to provide basic information, including problem situation, about the students' transfer of learning in econometrics for the development of the draft learning model. This phase is divided into two steps:

1. Research the relevant literatures.

2. Survey students' problem situations, teachers' opinion through interview.

Step 1: Research the relevant literatures

The goal of this step is to research literature on learning transfer and to craft a learning model that effectively promotes this transfer.

Key documents that highlight the importance of transfer include the "Modernization of Education in China 2035" and the "Guidelines for Advancing the

Transformation of Undergraduate Education and Enhancing the Cultivation of Talent Quality," both of which are issued by the Ministry of Education. Furthermore, academic conferences focused on the field of learning transfer, such as the IJCAI 2021 International Symposium on Federated Learning and Transfer Learning, offer invaluable insights.

Academic reports, research documents, and theoretical frameworks are essential tools in the development of a learning model designed to enhance learning transfer. Prominent academic reports include "How to Cultivate Students' Application and Transfer Abilities to Solve Real-World Problems?" authored by Hu Weiping, as well as "Knowledge Learning and Application." Research documents cover a range of topics, including reviews of learning transfer, methodologies, teaching activities, assessment strategies, and relevant theories. Theoretical frameworks such as the knowledge spiral theory, constructivism, and learning strategies play a pivotal role in this developmental process

Step 2. Interview students and teachers.

The purpose of this step is to understanding problem, potential reasons and opinion in transfer of learning in econometrics by interview students and teachers using the technique of informally goup interview.

Interview sample group:

Interview students: the sample group is composed of 15 students. They are from the Economics major. These students are in their fourth year at Zhanjiang Science and Technology College, located in Guangdong Province, China. They have successfully completed all their coursework. They are divided into 3 groups, with 5 students in each group. Out of the 6 classes in the Economics major, 2 classes were randomly selected. In the first class, 7 students were randomly selected, and in the second class, 8 students were randomly selected.

Interview teachers: 3 teachers who instruct Econometrics.

Research tools:

The tools for interviewing teachers and students are the "Teacher Interview Record Form" and the "Student Interview Record Form," respectively. The procedures to create this research tool are:

1. Acquire the skills to design an interview questionnaire for research purposes.

2. Establish the goals and precise inquiries for the group interview setting.

3. The questionnaire was endorsed by professional peers, including the Dean of the School of Economics and Finance and the Economics program coordinator at Zhanjiang Science and Technology College in Guangdong, China, who verified the logic of the questions and the terminology used. Additionally, it received approval from the ethics committee at Sinakarinthirat University, which ensured there were no ethical concerns.

4. Based on peer feedback, adjustments were made to the interview questionnaire.

5. The questionnaire is readied for conducting interviews with students and educators.

Data Collection and Analysis from Interviews:

The researcher conducts interviews with three groups of students and three educators, gathers interview data, and performs a content analysis on the collected interview information.

Phase 2: Learning model development

The process of developing the learning model in this study is bifurcated into two main components. The initial component encompasses the sequential stages of model development, totaling seven distinct steps. The subsequent component involves a peer review of the learning model by experts.

Learning model development steps:

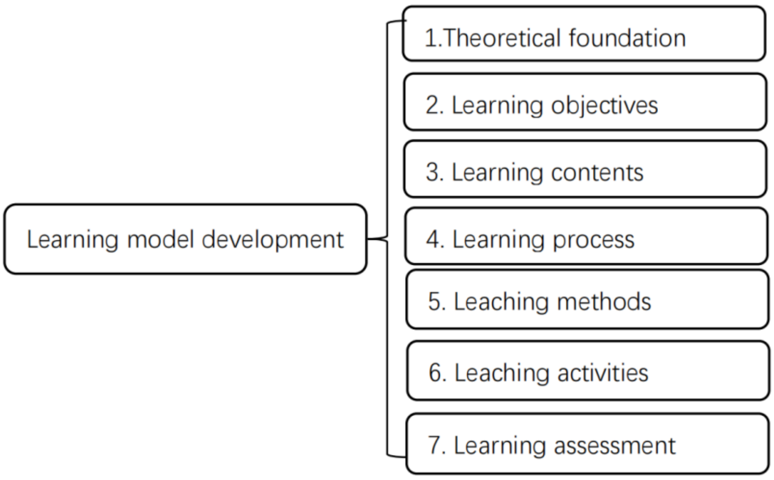

Figure 8 Learning Model Development Steps

Step 1: Develop theoretical foundation

In this study, the theoretical foundation for the development of the learning model is closely aligned with the reform pathways of applied undergraduate education, and the core requirements for cultivating the key competencies of applied talents. It integrates methodologies such as constructivist learning, cognitive and metacognitive development, knowledge spiral theory and transfer of learning theory, establishing a robust basis for the learning model's development.

Step 2: Develop learning objectives

In accordance with the educational transfer goals set forth in the "National Outline for Medium and Long-Term Education Reform and Development (2010-2020)" and the course learning requirements and Cultivation objectives pointed out in the syllabus for Econometrics, the learning objectives of this study are established to enhance students' transfer of learning and cultivate students' competency to solve problem.

Step 3: Selection and organization of Learning contents

The selection of learning content is based on the syllabus for the Econometrics course of the third-year students, the textbook "Econometrics" by Zinai Li, 5th edition, and the "Econometrics" case library. Topics related to the learning objectives and instructional design of econometrics, and learning strategies are analyzed. The literature on strategies that facilitate learning achievements and the transfer of learning has been studied. The procedures for organizing the learning content to "develop a learning model to enhance learning transfer" are:

1. Select the content of the econometrics course.
2. Analyze the course content and select suitable cognitive strategies to introduce.
3. Based on 1 and 2, choose appropriate metacognitive strategies to introduce.

After selecting and organizing the learning content, the next step is the information assembly of the content area, including the expected learning outcomes, the potential of the learners, the learners' previous learning experiences, and the characteristics and needs of the learners.

Applying the learning model to learn the content of the 5 units of econometrics includes:

Table 5 The Learning Content in Econometrics

<table>
<tr><td>num</td><td>Date</td><td colspan="3">Content</td><td>class</td></tr>
<tr><td>Unit 1</td><td>2024.3</td><td>Simple Linear Regression Model</td><td rowspan="5">Cognitive strategies</td><td rowspan="5">Metacognitive strategies</td><td>9</td></tr>
<tr><td>Unit 2</td><td></td><td>Multiple Linear Regression Model</td><td>9</td></tr>
<tr><td>Unit 3</td><td></td><td>Dummy Variable Model</td><td>6</td></tr>
<tr><td>Unit 4</td><td></td><td>Model that relaxes basic assumptions</td><td>12</td></tr>
<tr><td>Unit 5</td><td></td><td>Time series econometric model</td><td>9</td></tr>
</table>

Step 4: Develop learning process

The learning process demonstrates the basic structure of the learning model. The learning process was developed using the information of knowledge spiral structure and constructivism theory from the first step and learning contents, following the procedures below.

1. Divide learning process into stages, according to learning objective and learning contents.

2. Determine learning objectives for each stage, evaluate the depth and complexity of learning objectives at each stage.

3. Analyze learning content that is appropriate for each stage, with each stage increasing in complexity based on the previous one.

4. Design a learning process that requires iteration and repetition to deepen understanding.

5. Present the learning process structure diagram.

Step 5: Develop learning methods

Selecting appropriate learning methods is extremely important. Teachers should flexibly choose and apply various learning methods based on the characteristics of the students, learning objectives, and educational needs, so as to enhance students' interest in learning and their academic achievements. This research mainly determines the teaching and learning methods based on the GRR model, including direct teaching by the teacher, scaffolding, teacher guidance, cooperative learning, and independent learning.

Step 6: Develop learning activities

The design of learning activities must not only be consistent with the learning objectives, stage goals, and learning content, but also follow the learning process and teaching methods, as well as the students' foundation, potential, and learning needs.

Learning plan consist of three important parts.

1. Teaching objectives

2. Teaching content

3. Analysis of academic situation

4. Analysis of Important point in teaching

5. Teaching and learning activities

6. Time arrangement

7. Teaching summary and reflection

Step 7: Develop learning assessment

Student learning assessments include formative assessments and summative assessments. Formative assessment is an ongoing assessment process that runs throughout the entire learning process, with the purpose of providing timely insights, such as questioning, observation, students group work, group discussions, peer assessments, self-assessments, etc. During the learning process, teachers observe students' behavior and attitudes, and after each stage of learning is completed, students must fill out a self-assessment form.

Summative assessment is conducted at the end of the learning period, where students must participate in tests to measure their learning achievements or outcomes. The performance of the control group and the experimental group will be compared after the examination.

The formative assessment tool is

1. Teacher’s classroom observation record form

2. students self-assessment form

The summative assessment tool is

1. two types of tests:

1) Vertical Transfer - apply A to solving problem after learning A test

2) Horizontal Transfer - learning B after learning A test

2. student’s interview record form

Two types of tests designed following the procedure below:

1. Clarify the objectives and purposes of the test, such as assessing students' mastery of specific topics.

2. Develop a test outline based on course standards or learning objectives, listing the knowledge points and skills to be assessed.

3. Write various types of questions according to the test outline, such as multiple-choice questions, fill-in-the-blank questions, short-answer questions, and essay questions.

4. Check for ambiguity, errors, or inappropriate content in the questions.

5. Develop clear grading standards for each question or type of question.

6. Arrange all questions and grading criteria in a logical order to form a draft test. Conduct a format review to ensure that the format, layout, and instructions of the test are clear and easy to understand and answer.

7. Invite the 3 econometrics teachers from Phase 1 to evaluate the draft test and provide feedback. The evaluation mainly includes clarity, relevance, and appropriate difficulty.

8. Revise the test questions based on the opinions of the three teachers

Students self-assessment form designed following the procedure below:

1. Determine assessment objectives, such as, assess students' mastery of basic knowledge, cognitive strategies, and metacognitive strategies for each unit.

2. Determine the number of questions for each unit based on the course content and the proportion of class hours each unit occupies.

3. Design questions. Questions should cover the key points of all assessment areas.

4. Determine scoring method for the assessment form, such as Yes/No or Agree/Disagree scales.

5. Integrate the questions and scoring method into a preliminary assessment form draft.

6. Invite 5 experts in the field to review the assessment form to ensure its rationality. These five experts are the same group of individuals as the learning model assessment specialists.

7. Make necessary revisions to the assessment form based on feedback from expert opinions.

Interview sample group

5 randomly selected students from the experimental group of 44 were interviewed.

Teacher's classroom observation sample group.

The sample here and the sample interviewed by the phase1 teachers are the same group of people, consisting of 3 econometrics teachers

Collecting and analyzing data

After the completion of each unit, experimental group students are organized to take tests, and a difference analysis is performed between the control and experimental groups. Self-assessment forms are distributed to students at the end of each unit for data analysis.

After the entire learning process, student opinion interviews are conducted, teachers' classroom record forms are collected, followed by content analysis of the data.

Experts learning model assessment

The purpose of expert assessment is to evaluate the components of learning model before implementation, enhancing its effectiveness.

In this study, the five experts evaluating consistency and appropriateness of learning model objective, learning process, learning contents, method, activities and assessment instrument.

The appropriateness evaluation draws on the method of Koocharoenpisal (2005)to check the degree of match between the components of the instructional design. The consistency evaluation uses Item Objective Consistency (IOC).

Five experts come from Zhanjiang University of Science and Technology, Guangdong province, China. Two learning model development experts, an expert in the field of instructional evaluation, two Econometrics teacher. They all hold the titles of associate professor and professor.

The learning model will be modified based on the experts suggestions.

Research tool

The Expert Assessment Form is structured into four distinct sections,

Section 1: Personal Information Section captures the expert's professional background, emphasizing their academic title and qualifications.

Section 2: Element Appropriateness Assessment includes the alignment of the learning model process with educational goals, the relevance and appropriateness of the learning content, the effectiveness of the learning methods employed, the suitability of the learning activities in achieving the intended outcomes.

The appropriateness assessment of the learning model draft adopts a 5 - level rating system, as follows:

The evaluation criteria for determining the level of suitability are outlined below, with corresponding numerical values:

Scale values for suitability levels:

Very high suitability = 5 points

High suitability = 4 points

Moderate suitability = 3 points

Low suitability = 2 points

Very low suitability = 1 point

The scoring ranges for each suitability level are as follows:

4.51 to 5.00 = Very high suitability

3.51 to 4.50 = High suitability

2.51 to 3.50 = Moderate suitability

1.51 to 2.50 = Low suitability

.00 to 1.50 = Very low suitability

Section 3: Element Consistency Assessment evaluates the coherence among different elements to ensure a seamless learning experience, including the match between the learning objectives and the learning process, between the learning content and the activities designed to engage learners, between the learning methods and the activities that facilitate learning.

The alignment of the learning model's components was assessed using the Index of Item Objective Consistency (IOC). Scores are categorized into three levels:

Consistency level and corresponding scale values:

Consistent = +1 point

Uncertain = 0 points

Inconsistent = -1 point

The benchmark for internal consistency among the curriculum components is an IOC value exceeding 0.5. The IOC is calculated by dividing the total scale value assigned by the experts by the number of experts participating in the evaluation.

Section 4: Expert Opinion Section presents the expert's comprehensive evaluation, offering insights and recommendations based on the assessments conducted in the previous sections.

Designing the experts assessment form includes several key steps:

1. Reviewing relevant materials to learn about the creation of assessment forms.

2. Designing the structure of the assessment form.

3. Developing the content for the assessment.

4. Inviting expert (an expert in the field of teaching evaluation from the Economics Department of Zhanjiang Science and Technology College) to evaluate the content of the assessment form.

5. Adjusting the content based on the expert's evaluation.

Data Collection and Analysis

The researcher provided a draft of the learning model and the expert assessment form to five experts, who then conducted evaluations and returned their results. The researcher collected the expert evaluation data and analyzed the consistency and appropriateness of the learning model draft based on established criteria.

After the researcher analyzes the experts opinions from the expert assessment forms for revision, the effectiveness of the learning model draft is improved.

Phase 3: Learning model implementation and evaluation

Deployment of the Learning Model:

The objective of deploying the preliminary learning model is threefold: to determine its practicality, to assess its efficacy through the data obtained from the deployment, and concurrently, to collect feedback and insights for the model's enhancement.

Experimental design:

Population

The population of this study includes 271 third year students majoring in economics from 6 classes at Zhanjiang University of Science and Technology(Z University) in Guangdong Province, China. There are approximately 45 students in each classroom.

Sample

The study involves a group of 89 third-year economics majors from Z University, who are divided into two classes. Using cluster sampling, these two classes were chosen from a total of six. One class was designated as the experimental group, comprising 44 students, and the other as the control group, with 45 students. The aim is to compare the assessment outcomes between these two groups.

The researcher compared the statistical grades of students from both classes from the semester prior to the study and performed an analysis of variance on the mean scores. The findings indicated that there was no significant disparity in the statistical grades between the two classes in that previous semester.

Research tool

The research tools for the experiment include:

1. Statistics grades of previous semester from the two sample classes.

2. Learning plan and teaching materials.

3. Two types of test papers and grading criteria.

4. Student self-assessment form.

5. Student’s interview record form.

6. Teacher classroom observation record form.

Data collection

The researcher is tasked with teaching the Econometrics course for junior college students majoring in Economics in the second semester of 2024 academic year, at Zhanjiang Science and Technology College, Guangdong Province, China. The researcher has communicated with the dean of the School of Economics and Finance and the head of the Economics department and received support to implement the learning model draft and collect data during the 15 weeks from March to June 2024. The procedures for learning model implementation and data collection are as follows:

1. The preparatory work before the implementation of the learning model includes:

1) Prepare documents on “the learning model to enhance students’ transfer of leanring”, including the learning model diagram, learning plan, teaching materials, and assessment tools.

2) Train teaching assistants on the purpose of the learning model, learning process, its implementation, and expected outcomes.

3) Introduce the learning model to the students, explaining its structure, goals, and the benefits they can expect from engaging with it.

2. Implementation learning model

1) Carry out the planned classroom activities

The sample experimental group and control group were taught Econometrics by the researcher, with the experimental group using the learning model developed in this research, and the control group using traditional learning methods. Traditional learning method usually refers to education that is centered around the teacher, emphasizing classroom instruction and textbook learning. These methods tend to focus more on mastering and restating existing knowledge rather than paying attention to students' cognitive patterns and the cultivation of their cognitive and metacognitive strategies.

2) Test

The test including two types according to definition of transfer of learning:

Table 6 Two Types of Test

Stage 1	Stage 2
Leaning A	Test the performance of applying A- Vertical Transfer
Leaning A	Test the performance of learning B (Pre-study Task Test) - Horizontal Transfer

Upon the conclusion of each instructional unit, two distinct assessments were given to students in both the experimental and control groups. The first assessment was designed to evaluate the students' capacity to apply prior knowledge to problem-solving tasks. Additionally, students were tasked with self-study the forthcoming econometrics unit before taking the second assessment, which gauged their mastery of new material.

Throughout the instructional period, the instructor monitored and documented various aspects of the learning process, such as the students' emotional states and behavioral responses. Following each unit, self-assessment questionnaires were provided to the experimental group to gauge their perceptions, progress, and learning outcomes. After the 15-week course, interviews were conducted with the students to elicit their feedback on the teaching methods employed. This information was integrated into the learning model's data set.

Post-Implementation Learning Model Assessment

The evaluation of the learning model's effectiveness is based on several criteria:

1. Post-instructional application test scores for the experimental group exceed those of the control group with statistically significant differences.

2. Post-study new content test scores for the experimental group surpass those of the control group with statistically significant differences.

3. Self-assessment scores for the experimental group show a progressive increase.

4. Teacher observations indicate that the experimental group's performance is superior to that of the control group.

Learning model revision

Based on the data collected from the implementation and evaluation of the learning model, the model is revised again. Data analysis is conducted on the final student interview record forms and learning outcomes records.

Ethical consideration

This questionnaire applying in this research aim to survey students' transfer of learning majoring in economics in Zhanjiang University of Science and Technology. Before survey, researcher has told students that their participation is voluntary and they have the right to withdraw consent or discontinue participation at any time without penalty. They have known that there are no other benefits except that they will receive a copy of the study materials after the questionnaire as compensation.They have the right to refuse to answer particular questions. Their answer is anonymous and individual privacy will be maintained in all publications resulting from this study.

The researcher sought their consent on recording their response for future analysis. Researcher promise that the data collected from this survey is only used for statistical analysis and to keep the collected data strictly confidential.

CHAPTER 4

FINDINGS

This section details the application of the spiral-GRR learning model aimed at bolstering the transferability of students' econometrics knowledge and provides an analysis of the data outcomes. The research results are categorized into three main sections, aligning with the objectives set forth in the initial chapter:

1. To research the definition and contents of transfer of learning, and problem situation for college students;

2. To develop a learning model that integrates spiral structure, GRR model, and strategic learning, with the aim of enhancing college students' learning transfer ability;

3. To assess the effectiveness of the learning model in improving students' learning transfer ability following its implementation in econometrics course.

The specific research findings are described in detail as follows:

4.1 Research findings to research the definition and contents of transfer of learning, and problem situation for college students

4.1.1 Relevent literature research results

Through searching academic resource databases such as the official website of the Chinese Ministry of Education, China National Knowledge Infrastructure (CNKI), Srinakharinwirot University Central Library Electronic Resources in Thailand, Google Scholar, TeachThought, Web of Science, and the Educational Resources Information Center (ERIC), using the keywords " transfer of learning", relevant literature was obtained. The following four aspects of findings were organized through reading the literature:

1. Several perspectives emphasize the importance of transfer of learning

The significance of learning transfer has been highlighted across nine scholarly works, emphasizing its role as a core educational objective, its integration of theoretical knowledge with practical application, its role in cognitive growth, and its relevance to educational interventions.

Nevertheless, it is commonly acknowledged that learning transfer presents significant challenges, particularly in achieving far transfer, and in certain instances, learning in one area may result in negative transfer affecting performance in another area.

2. Definition of Learning Transfer

The concept of learning transfer, or the influence of one learning experience on another, is widely recognized as the effect of acquired knowledge and experience on the performance of other tasks. This phenomenon is prevalent in the acquisition of knowledge, skills, attitudes, and behavioral norms. Learning transfer can be categorized from various standpoints, including positive and negative transfer, forward and backward transfer, and horizontal and vertical transfer. Near transfer typically occurs between closely related domains, while far transfer is observed between domains with less direct relevance. Numerous studies have indicated that achieving far transfer within a short timeframe is challenging.

Here, horizontal transfer refers to what happens between tasks of similar difficulty and generality levels. Learners apply the skills, strategies, or knowledge they have learned in one task to another task, which is structurally similar.

For example, a student may apply the learning strategies learned in the third part of econometrics to the study of the fourth part.

Vertical transfer involves bottom-up (from concrete to abstract) or top-down (from abstract to concrete). In top-down vertical transfer, learners apply the concepts or principles they have mastered to new specific contexts.

For example, learners may apply the econometrics modeling methods and testing principles they have mastered to specific problem-solving situations.

This forms the definition of transfer of learning in this research. Table 7 presents the design of learning and measurement for transfer of learning according to definition.

Stage 1 is learning process, stage 2 is measurement. Two aspects of measurement is measurement of Horizontal transfer and Vertical transfer.

Table 7 Definition of Transfer of Learning

	Stage 1	Stage 2	Transfer of learning
1	Learning A	Applying A to solving problem	-Horizontal transfer
2	Learning A	Learning B(Pre-study)	-Vertical transfer

3. Content of transfer of learning

Through a synthesis of the literature read, the content of learning transfer includes the following aspects: Knowledge transfer, such as facts, concepts, and principles; Skill transfer, such as transitioning from learning to ride a bicycle to riding a motorcycle; Strategy transfer, such as note-taking skills, problem-solving strategies, etc.; Attitude and belief transfer: such as learners' attitudes, values, and beliefs; Cognitive structure transfer, such as changes in cognitive structures or thinking frameworks due to learning, which may affect subsequent learning; Context model transfer; Metacognitive transfer: The learners' awareness and management abilities of their own cognitive processes, i.e., metacognitive skills, can be transferred between different learning tasks; Emotional transfer; Discipline-specific transfer and interdisciplinary transfer.

The transfer in this research refers to near transfer occurring within the same discipline-econemetrics. It is commonly believed that transfer within the same discipline relies on a common knowledge base, set of skills, discipline-specific ways of thinking, and learning strategies. In addition, some literature points out that cognitive strategies are task-specific and therefore limited in transfer, this has been pointed out in Chapter 2.

Thus, the content of transfer of learning in this research including:

1) Transfer of knowledge

2) Transfer of experience in applying cognitive strategies

3) Transfer of metacognitive strategies

4. Methods to enhance transfer of learning

It is widely believed that educators can promote the occurrence of these transfers and thereby improve the efficiency and depth of learning by designing learning and teaching activities. They have proposed methods such as Project-Based Learning (PBL), Case Study Method, and Anchored Instruction for situational transfer; Cognitive Apprenticeship, Problem-Based Learning (PBL) and Metacognitive strategy training for the transfer of knowledge and skills; and models that emphasize critical thinking, problem-solving, and the application of knowledge like the Deep Learning Model and the Collaborative Learning Model; Reflective Practice Model, etc.

However, there is no comprehensive learning model designed for transfer content that includes a variety of teaching methods.

4.1.2 Student and teacher interview results

1.Student interview results

The student interviews covered the econometrics transfer and application, the difficulties in learning, and effective learning methods. Interviews were conducted with 3 groups, each consisting of 5 fourth-year economics major students who have completed their coursework.

1)"Do you think econometrics has application value in academic research? Please give an example”

Students believe that the study of econometrics has practical application value, reflected in the learning of other courses, the writing of thesis papers, and the job skills required for internships.

"We believe that the study of econometrics is very valuable in academic research. For example, in my course project on market analysis, I used econometric models to predict consumer behavior." (Group 1)

"Econometrics is very useful for understanding economic phenomena and making predictions. I applied econometric methods in my thesis to analyze the impact of economic policies." (Group 2)

"Econometrics is very important in academic research, especially when conducting empirical analysis. I applied these skills in a research assistant position to analyze economic data." (Group 3)

2) "What is the biggest challenge you have encountered in the application after learning?"

Students believe that after completing the course, they will encounter difficulties in application, and one group thinks their biggest difficulty lies in not knowing how to choose the model.

"For us, the biggest challenge is understanding the assumptions of different models. In practical applications, I often don't know which model to choose." (Group 1)

3) "Looking back on your learning experience, which part of the teaching process do you think has been most helpful to you?"

Students reviewed their past learning experiences and believed that teacher demonstrations, group discussions, case studies, and reflection methods were all very helpful to learning.

"I found the practical exercises in the classroom very helpful, especially when the teacher demonstrated how to solve problems step by step." (Group 1)

"I think the group discussion session was very effective because it allowed us to share different perspectives and methods for solving problems." (Group 2)

"I found the case study session most helpful. By analyzing real economic data, I was able to understand the application of econometrics more deeply. The reflective writing tasks assigned by the teacher were also very helpful. This learning strategy gave me the opportunity to review and think about my learning process in the course, to identify my strengths and areas for improvement." (Group 3)

2. Teacher interview results

The teacher interviews cover the performance of students' learning transfer, potential influencing factors, and the measurement methods of learning transfer. Interviews are conducted with 3 teachers in the economic major.

1) "In your teaching experience, how have you observed students' performance in learning transfer between different course units? Specific examples?"

Teachers generally believe that students' learning transfer performance varies.

"Students' learning transfer between course units is usually affected by their in-depth understanding of knowledge. Students who can deeply understand the concepts tend to perform better in transfer. For example, students who understand the principles of economics can more easily apply these principles to different economic models." (Teacher A)

"I have observed that students' learning transfer performance varies between different course units, and the use of cognitive strategies is a key factor. For example, some students can use comparison and contrast strategies to connect the concepts of different units, while other students have difficulties in this integration." (Teacher B)

"In my experience, students perform better in knowledge transfer when using cognitive strategies such as induction and deduction. Specific examples include students applying statistical methods learned in one unit to data interpretation in another unit." (Teacher C)

2) "What do you think may hinder students from effectively transferring learning in the course?"

Teachers believe that students' learning strategies, cognitive flexibility, and levels of metacognitive development affect learning transfer.

"The different levels of students' metacognitive development may affect their ability to transfer. I help them overcome transfer barriers by encouraging students to monitor their understanding and reflect on the learning process." (Teacher A)

"One of the challenges I have observed students encountering in knowledge transfer is their lack of in-depth mastery of previously learned content, which limits their ability to apply this knowledge. This is usually related to the lack of effective memory and comprehension strategies." (Teacher B)

"The obstacles to students' knowledge transfer in the course may include insufficient adaptability to new situations, which is related to their cognitive flexibility and creative thinking strategies." (Teacher C)

3) "How do you evaluate and measure students' transfer in the study of a course?"

"I usually assess students' transfer ability through project assignments. I observe how they apply a concept to different situations." (Teacher A)

"I include questions or activities in preview tasks that allow students to demonstrate how they apply prior knowledge to new learning content. Or through self-study tests, to assess students' knowledge retention and transfer ability." (Teacher B)

We found teachers usually use project assignments and self-study tests to assess students' learning transfer in this course.

In summary, Learning transfer ability refers to the student's capacity to apply knowledge, skills, attitudes, and strategies acquired in one context to new contexts. This ability encompasses two main aspects:

When applying what has been learned, students should be able to identify problems, propose solutions, and solve problems in practice.

When learning new content (pre-study), students should be able to recognize the connections between old and new knowledge, apply effective learning strategies used in previous learning processes to new learning tasks, demonstrate a sustained interest and positive attitude towards learning new knowledge, and show flexibility and adaptability in skills.

The problems students face in learning transfer include: 1) A lack of awareness of the connections between new and old knowledge, which prevents them from effectively applying what they have learned to new situations; 2) A deficiency in effective learning strategies, making it difficult for students to tackle new learning tasks; 3) A lack of interest and a positive attitude towards learning new knowledge, which affects the motivation and persistence of learning transfer; 4) A lack of flexibility and adaptability, making it hard for students to adjust their learning methods and strategies when faced with different or unknown learning situations.

4.2 Research findings to develop a learning model with the aim of enhancing students' learning transfer ability

In this research, researcher aim to develop a Spiral GRR learning model to enhance the transfer of learning for college students. Therefore, based on the literature review and interviews conducted in phase 1, the definition of transfer of learning and relevant information about developing learning model has been understood. The research integrating definition, knowledge Spiral Theory, GRR model, learning strategies, and constructivist theory, has developed the following learning model, named spiral GRR learning model.

4.2.1 Spiral GRR learning model

Step1: Theoretical foundation

Based on literature research, GRR is a teaching model that emphasizes the gradual shift of responsibility from the teacher to the student during the teaching and learning process, fostering the ability to learn and apply independently. The spiral structure of knowledge refers to the organization of learning content and processes, allowing students to deepen their understanding of knowledge through a series of activities that are repetitive but gradually increase in complexity. In this study, the Spiral-GRR model refers to the application of the GRR method to each stage of the spiral learning structure. While GRR ensures the learning outcomes at each stage, the progression and repetition of the spiral structure promote students' gradual and deeper understanding, ultimately developing the ability for independent learning and transfer of application.

This research designed a Spiral-GRR learning model and implemented it in the practice of econometrics courses. The spiral structure consists of three levels: 1) the level 1 involves exposure to new knowledge, including basic concepts, facts, and principles; 2) the level 2 begins to introduce cognitive strategies during the review of knowledge; 3) the level 3 introduces metacognitive strategies, such as strategies for monitoring and adjusting one's own learning process, to support deeper learning and understanding. This hierarchical learning model improve the superficial memory and repetition of traditional learning as well as the neglect of the learning process, integrating knowledge points and strategy learning into a coherent learning path. As the complexity of learning tasks gradually increases, students' adaptability is improved. It also improves the traditional learning's neglect of students' metacognitive development, by gradually introducing cognitive and metacognitive strategies, students can understand more comprehensively, take charge of their learning process, and develop cognitive flexibility. The learning model provides students with a comprehensive, in-depth, and highly adaptable learning experience.

The learning model development process in this research is deeply inspired and supported by the theories of knowledge spiral theory, learning strategies, GRR model, constructivism theory, and transfer of learning. These theories form the theoretical basis for the Spiral-GRR learning model, the construction of the learning process, and the design of teaching content and methods. Researcher have provided reference from multiple aspects to establish the theoretical framework of the Spiral-GRR learning model.

Learning model :

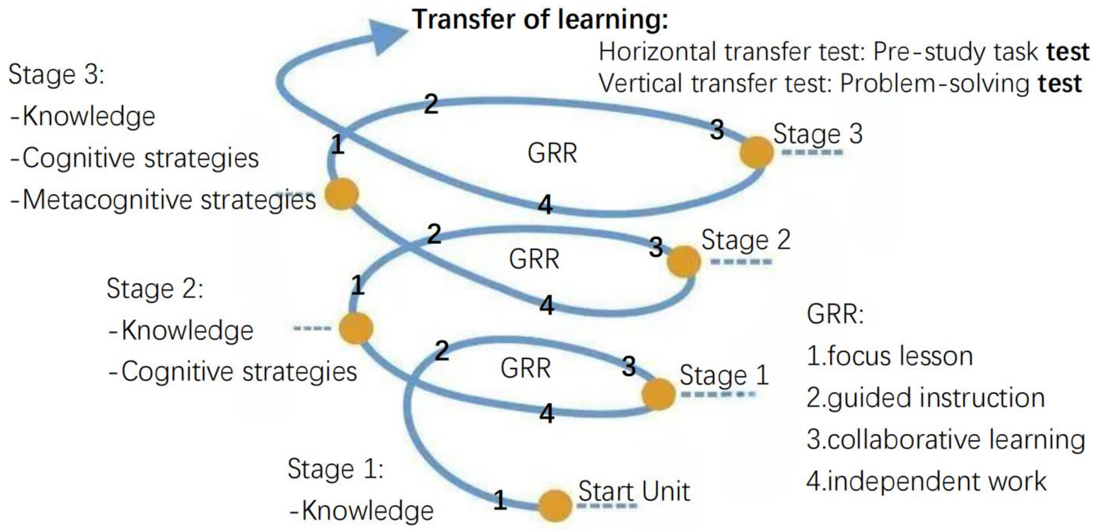

Figure 9 Spiral GRR Learning model

The researcher developed the learning model to enhance students' transfer of learning and implemented it in the teaching and learning of econometrics.

The spiral structure consists of three levels:

The level 1 involves exposure to new knowledge, including basic concepts, facts, and principles;

The level 2 begins to introduce cognitive strategies during the review of knowledge;

The level 3 introduces metacognitive strategies, such as strategies for monitoring and adjusting one's own learning process, to support deeper learning and understanding.

This learning model aims to enable students:

When applying what has been learned, students should be able to identify problems, propose solutions, and solve problems in practice.

When learning new content(Pre-study), students should be able to recognize the connections between old and new knowledge, apply effective learning strategies used in previous learning processes to new learning tasks, demonstrate a sustained interest and positive attitude towards learning new knowledge, and show flexibility and adaptability in skills.

Step 2: Learning·objectives

The main objective of this learning model is to meet the requirements for enhancing transfer of learning. The model is implemented in the learning of econometrics courses. The learning model should provide a rich introduction to strategies and ample opportunities for practice, guiding students to gradually acquire knowledge, experience in applying cognitive strategies, and metacognitive strategies. It facilities students to actively participate in the classroom, engage in reflection and self-assessment, and promote deep learning.

This learning model aims to enable students to be adept and effective in utilizing strategic tools, maintaining an in-depth understanding and reflection of the content learned.

When applying what has been learned, students should be able to identify problems, propose solutions, and solve problems in practice.

When learning new content(Pre-study), students should be able to recognize the connections between old and new knowledge, apply effective learning strategies used in previous learning processes to new learning tasks, demonstrate a sustained interest and positive attitude towards learning new knowledge, and show flexibility and adaptability in strategies.

Step 3: Learning content

The selection of learning content is based on the textbook "Econometrics" by Li Zinai, fifth edition, and the syllabus of the Econometrics course. The first 5 units of the textbook are chosen as the content for learning model practice, which are Univariate linear regression, multiple linear regression, dummy variable models, Model that relaxes basic assumptions and Time series econometric model. Researchers have analyzed topics related to the design of econometrics teaching content. This study focuses on strategic learning, deep learning, and the development of metacognition, and is a learning model theme design about "developing a spiral GRR learning model to improve students' transfer of learning."

Economics majors, who are in their third year, have already learned statistics courses last year, and they have a certain understanding of data collection, description, and analysis. Students have been exposed to the basic principles of economics, which helps them understand the economic significance of econometric models. Students have also been exposed to scientific research methods, which aids in their understanding of the design and implementation of econometric research.

This research integrates the learning content of econometrics textbooks and syllabi with cognitive strategies and metacognitive strategies, reorganizing the learning content. The learning content consists of 5 units. 3 classes per week, for a total of 15 weeks. each class period lasting 45 minutes.

Unit 1 Univariate Linear Regression(9 classes)

1. Knowledge Learning

---- Definition and basic assumptions

---- The principle and calculation process of the least squares method

---- Parameter estimation and interpretation of the regression line

2. Cognitive Strategies

---- Visual teaching: Use diagrams to display data points and fitting lines to enhance intuitive understanding.

---- Step-by-step guidance: Guide students step by step from data collection to model estimation.

---- Problem-solving: Deepen the understanding of the application of simple linear regression by solving practical problems.

3. Metacognitive Strategies

---- Self-monitoring: Encourage students to monitor their own learning progress and depth of understanding.

---- Learning reflection: Reflect after learning each concept to ensure correct understanding.

---- Strategy adjustment: Adjust learning strategies according to personal understanding, such as repeating exercises or seeking help.

Unit 2 Multiple Linear Regression(9 classes)

1. Knowledge Learning

---- Construction and interpretation of the multiple linear regression model

---- The problem of multicollinearity and its diagnostic methods

---- Hypothesis testing of the model and model selection criteria

2. Cognitive Strategies

---- Case analysis: Teach how to introduce and interpret multiple explanatory variables through case analysis.

---- Group discussion: Encourage students to discuss the impact of different variables on the model within groups.

---- Software simulation: Use statistical software for multiple linear regression analysis to deepen the understanding of the model.

3. Metacognitive Strategies

---- Concept integration: Guide students to integrate the concepts of multiple linear regression with those of simple linear regression.

---- Self-assessment: Regularly conduct self-assessment during the learning process to ensure understanding of the model.

---- Learning goal setting: Help students set specific learning goals and track the achievement of these goals.

Unit 3 Dummy Variable Model(6 classes)

1. Knowledge Learning

---- Definition and function of dummy variables

---- Different types of dummy variable encoding methods

---- Application and interpretation of dummy variables in regression models

2. Cognitive Strategies

---- Situational simulation: Teach the application of dummy variables by simulating different economic situations.

---- Comparative learning: Compare the dummy variable model with the ordinary regression model to deepen the understanding of differences.

---- Practical operation: Deepen the understanding of dummy variable encoding and application through practical operation of data.

3. Metacognitive Strategies

---- Learning monitoring: Teach students how to monitor their own learning progress and depth of understanding.

---- Error identification: Encourage students to identify and correct errors in practice promptly.

---- Application reflection: Reflect on the applicability and limitations of the dummy variable model after its application.

Unit 4 Model that relaxes basic assumptions(12 classes)

1. Knowledge Learning

---- Overview of the basic assumptions in the classical linear regression model.

---- Examination of issues arising from violations of these assumptions, including:

1) Multicollinearity: Causes, detection (e.g., variance inflation factor), and remedies (e.g., ridge regression, principal component regression).

2) Heteroscedasticity: Causes, detection (e.g., Breusch-Pagan test), and remedies (e.g., weighted least squares, heteroscedasticity-consistent standard errors).

3) Serial correlation: Causes, detection (e.g., Durbin-Watson test), and remedies (e.g., Newey-West standard errors, autoregressive errors).

4) Techniques for diagnosing and correcting model specification errors.

2. Cognitive Strategy Learning

---- Case Studies: Analyzing case studies where basic assumptions are violated to understand the practical implications.

---- Step-by-Step Problem Solving: Learning to diagnose and address specific issues step by step, from identifying the problem to applying the appropriate correction.

---- Software Application: Using statistical software to detect violations of assumptions and to implement corrective measures.

---- Comparative Analysis: Comparing models with and without violations to understand the impact on results and inferences.

3. Metacognitive Strategy Learning

---- Self-Regulation: Developing the ability to independently assess the need for diagnostic tests and to apply corrective actions.

---- Reflective Practice: Encouraging reflection on the process of model building, including the assumptions made and the rationale for chosen methods.

---- Learning Goal Setting: Setting specific learning objectives for mastering the diagnosis and correction of assumption violations.

---- Strategic Adaptation: Learning to adapt strategies based on the nature of the data and the specific violations encountered.

Unit 5 Time series econometric model(9 classes)

1. Knowledge Learning

---- Basic Concepts of Time Series Analysis: Definition of time series and its components (trend, seasonality, cycle, and irregular); Importance of time series in economic data analysis.

---- Stationarity Testing: Explanation of stationarity and its types (strict, trend-stationary, and seasonal); Techniques for testing stationarity, including the Dickey-Fuller test.

---- ARIMA Models: Components of ARIMA: Autoregressive (AR), Integrated (I), and Moving Average (MA); Model identification, parameter estimation, and forecasting.

2. Cognitive Strategy Learning

---- Data Manipulation and Visualization: Skills to manipulate time series data and create informative visualizations.

---- Model Identification and Diagnostics: Strategies for identifying the appropriate model for a given time series and diagnosing model fit.

---- Software Application: Proficiency in using statistical software for time series analysis, including model estimation and forecasting.

---- Comparative Analysis: Comparing different models' performance on the same data set to understand their suitability in various contexts.

3. Metacognitive Strategy Learning

---- Self-Assessment: Techniques for self-assessing understanding of time series concepts and model applications.

---- Learning Plan Development: Formulating a structured learning plan to master time series analysis, including milestones and checkpoints.

---- Critical Thinking: Applying critical thinking to evaluate the assumptions and limitations of time series models.

---- Reflective Practice: Reflecting on the learning process and model application to identify areas for improvement.

---- Adaptive Learning: Adjusting learning strategies based on feedback and new understandings gained from practice.

Step 4:·Learning·process

Based on the learning content above and the theories of knowledge spiral structure and constructivism, the learning process is developed.

The learning process is divided into three stages, with the goals of each stage being:

1) Understanding basic concepts and principles;

2) On the basis of understanding knowledge, learning and practicing cognitive strategies, such as using recitation through loud reading or silent reading, using analogies, concept maps for elaboration, and organizing knowledge through outlining, making tables, or using graphic organizers;

3) Acquiring metacognitive strategies, such as self-questioning, time management, monitoring one's own level of understanding and progress, etc., to promote students' self-regulated learning.

The analysis of the learning content for each stage is as follows:

1) The basic knowledge of simple linear regression, multiple linear regression, and dummy variable models;

2) Acquiring cognitive strategies such as data exploration, model building, and hypothesis testing;

3) Acquiring metacognitive strategies such as learning reflection, strategy selection, and problem-solving.

By gradually increasing the complexity of the learning objectives and content, the design structure of the learning process developed in this study is a three-stage spiral diagram.

Step 5: Learning·methods

Incorporating leaching techniques is a crucial aspect of crafting the learning model. Scholars have the flexibility to select and implement various instructional strategies, taking into account variables like student traits, educational goals, and subject matter. Throughout the stages of this learning model, the teaching and learning approaches incorporate the GRR framework, which stands for the gradual release of responsibility (refer to Figure 10). including four steps, and other teaching methods such as analogy teaching, in-depth inquiry, case resolution, and project-based learning. This research designs classroom activities for each stage according to the teaching and learning methods, enabling students not only to acquire new knowledge but also to practice and reflect through the acquired strategies, ultimately achieving the effect of transferring the learned to independent learning and problem-solving.

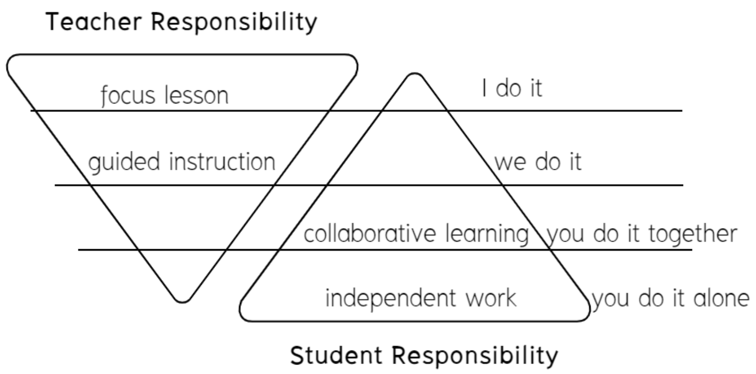

Figure 10 Fisher and Frey's Version of the GRR Model.

Source: Pearson et al. (2019). In The Beginning: the Historical and Conceptual Genesis of the Gradual Release of Responsibility p. 14.

The application of GRR in each cycle includes some specific methods, as follows:

1.focus lesson

Teachers:

Demonstration, Questioning

Students:

Active Participation, Note-taking

2.guided instruction

Teachers:

Gradual Guidance

Providing Question Frameworks

Feedback

Students:

Following Guidance

Asking Questions

3.collaborative learning

Teachers:

Organizing Group Work

Guiding Discussions

Students:

Communicating

Collaborating

4.independent work

Teachers:

Providing Resources and Guidance, Encouraging Reflection

Students:

Independent Learning

Self-Assessment

Reflecting

Step 6:·Learning·activities

The educational resources for the Spiral GRR learning model encompass both textual content and instructional aids, such as course materials, outlines, teaching plans, practice sheets, and evaluative instruments. The instructional aids comprise devices like whiteboards, presentation slides, and digital computers.

According to theoretical foundation, learning objectives and contents, the principles for designing teaching and learning activities are as follows:

1) Choose differentiated teaching strategies for knowledge learning.

The learning of declarative knowledge is mainly apply retelling strategies, precision processing strategies, and organizational strategies, such as guiding students to retell; Provide details, annotations, summaries, and create analogies for the materials to be memorized; Teachers provide students with structural outlines, guide them in constructing knowledge networks, and focus on the application of cognitive tools;

The learning of procedural knowledge is mainly apply internalization and application of procedural knowledge, which requires students to provide a declarative explanation of a certain skill and provide diverse situations for students to practice;

For the learning of cognitive and metacognitive strategies, teachers mainly demonstrate and illistrate the application of strategies, aloud thinking, monitoring and regulation of the thinking process, and require students to reflect and regulate the process of strategy application.

2) Teacher guidance is an important component of early learning, providing learners with support (such as modeling, guidance, scaffolding), and encouraging them to actively build their personal learning experiences (such as exploration, expression, reflection).

3) The teaching strategies of 'embracing' and 'bridging' help with learning transfer. Among them, the "embrace" strategy refers to teaching that directly allows learners to approach the target situation; The "bridging" strategy refers to instructional design that encourages abstraction, searching for possible connections, mindfulness, and metacognitive reflection to deepen understanding.

4) Situational case studies and experimental projects are the application of learned knowledge in various situations, and multiple stimuli similar to previous learning situations can train automated response patterns for transfer.

According to these principles for designing teaching and learning activities, The research design learning plan including learning themes, learning objectives, content, learning situation analysis, key teaching point analysis, learning activities, time allocation, summary, and reflection, among other main contents. (The learning plan see in appendix)

Step 7: Learning·assessment

1. Student Learning Process Evaluation

Evaluation forms include formative assessment and summative assessment.

1) Classroom-based formative assessments are implemented using diverse methods of evaluation, including verbal inquiries, in-class observations, collaborative student discussions, individual self-assessments, and one-on-one interviews.

2) Summative assessment is a test conducted after implementation to measure student performance or outcomes. A comparison of academic performance between control and experimental groups is made.

2. Development of Research Instruments for Data Collection

The research tools used for data collection include: 1) Learning Transfer Test; 2) Student Self-assessment Form; 3) Teacher Classroom Observation Record Form; 4)Student Opinion Survey Form on Teaching.

3. Expert assessment results

Scholars engaged professionals to perform a quality assessment of the educational model. A panel of five experienced educators evaluated the coherence and suitability of every component within the learning model.

4.2.2 Expert assessment and revision

The expert assessment results of the learning model design are divided into two parts:

1. learning model design consistency assessment
2. learning model design appropriateness assessment

The data analysis results are as follows:

1. Learning model design consistency assessment

Experts examined the consistency of the design of various elements of the learning model, including theoretical foundation, learning objectives, learning content, learning process, teaching methods, teaching activities, and learning assessment. After collecting data, researchers analyzed the data and conducted an evaluation. Data from the Item Objective Consistency (IOC) is presented in Table 8. The evaluation of consistency reveals that the IOC scores fall between 0.8 and 1.0, surpassing the benchmark of 0.5. This indicates that, based on the experts' assessment, the components of the learning model are aligned and consistent with each other.

Table 8 Consistency of Learning Model Design from Experts

NO.	List of evaluation	IOC
1	The Theoretical foundation with the Learning·objectives	0.8
2	The Theoretical foundation with Learning· process	0.8
3	The Theoretical foundation with Teaching·methods	1
4	The Theoretical foundation with Learning·assessment	0.8
5	The teaching objectives with the learning content	1
6	The teaching objectives with the teaching method	1
7	The teaching objectives with the learning assessment	1
8	The teaching contents with the Learning· process	0.8
9	The teaching contents with the teaching method	0.8
10	The teaching contents with the teaching activities	0.8
11	The teaching contents with the learning assessment	1

2. Learning model design appropriateness assessment

The appropriateness of the learning model design was assessed by inviting five experts using the appropriateness assessment form. The assessment method involved scoring various aspects of the learning model design, including theoretical foundation, learning objectives, learning content, learning process, teaching methods, teaching activities, and learning assessment. A quantitative assessment and scoring of the project were conducted, followed by the calculation of the average score and standard deviation.

The average score, standard deviation, and level of appropriateness of the learning model assessment are shown in the table 9.

Table 9 Appropriateness of Learning Model Design from Experts

NO.	List of Evaluation	mean	Std.	level
1	The Theoretical foundation· are appropriate for Learning·objectives	4.2	0.45	high
2	The learning objectives are appropriate for implementation	4.6	0.55	Very high
3	The learning objectives are appropriate for students	5	0	Very high
4	The learning contents are appropriate for the learning objectives	4.2	0.45	high
5	The learning contents are appropriate for students' learning	4	0	high
6	The learning processes are appropriate for the learning objectives	4.6	0.55	Very high
7	The learning processes are appropriate for the learning contents	4.6	0.55	Very high
8	The teaching materials are appropriate for the	4.0	0	high

	learning contents			
9	The assessment methods are appropriate for the learning contents	4.6	0.55	Very high
10	The assessment methods are appropriate for students	4.6	0.55	Very high
11	Time allocation in each learning unit is appropriate for learning of students	4.2	0.45	high
12	The contents objectives are appropriate for the needs of the course	5	0	Very high

In Table 9, the results of the appropriateness assessment show that the average scores range from 4.00 to 5.00, with standard deviations from 0.00 to 0.55, indicating that the learning model design is appropriate at a high to very high level.

3. Suggestion and revision

Experts provide suggestions for revising the elements of learning model design.

Firstly, it was suggested to add the principle of observation and timely feedback. The metacognitive transfer path based on GRR may not be smooth, so some experts proposed that it is crucial to always follow the principle of timely observation and feedback in teaching. When students do not consciously think about their processes or results, teachers should provide hints and help, and actively encourage students to express their thoughts, so that students can more clearly and accurately understand their learning situation and areas for improvement. Even though some other experts believe that this principle is similar to the second principle of teacher guidance, researcher still consider adding the feedback principle to reflect the importance of teacher guidance, student self-monitoring, self-regulation, and self-reflection, as well as the smooth transfer of metacognition in GRR.

Secondly, experts have suggested enriching teaching materials.

The learning plan was revised according to the experts' suggestions.

Firstly, the principle of observation and timely feedback was added, and the teaching principles were clearly explained during the implementation of teaching.

Secondly, Based on the experts' opinions, personalized learning resources, such as online tutorials and interactive tools, have been added to the learning plan.

4.3 Research findings to assess the effectiveness of the learning model in improving learning transfer ability

4.3.1 Result to implement learning model

1. Learning model implementation results

In the second semester of the 2024 academic year, which began in March 2024, researcher taught the Econometrics course to the third-year students majoring in Economics at Zhanjiang Science and Technology College in Zhanjiang City, Guangdong Province, China, implementing the spiral GRR learning model. The course lasted for 15 weeks, with 3 classes per week, each lasting 45 minutes. The experimental subjects were students from one class, totaling 44 individuals, while 45 students from another class served as the control group. This research utilized a random cluster sampling method to select two classes out of six third-year classes of the major as the sample.

1) Test

Two types of tests were conducted for the five learning units: horizontal transfer test and vertical transfer test. These tests were designed to evaluate the effectiveness of the learning model in improving students' transfer of learning. EXCEL and IBM SPSS Statistics Software was used for statistical analysis and summarization of data from the experiment.

The results of the learning model implementation are as follows:

(1) Horizontal transfer test and analysis

Table 10 presents the descriptive statistics of the horizontal transfer test scores for students in the experimental and control groups across the five learning units.

Table 10 *Descriptive Statistics of The Horizontal Transfer Test Scores for the 5 Learning Units.*

Test Time	Experimental Group Mean	Experimental Group SD	Control Group Mean	Control Group SD
Unit 1	43.34	5.06	41.95	5.66
Unit 2	45.91	5.89	44.97	6.15
Unit 3	46.66	6.06	41.84	5.45
Unit 4	45.73	5.36	40.62	5.77
Unit 5	47.36	5.91	43.55	5.80

The students in the experimental group demonstrated superior overall performance compared to their counterparts in the control group. Across all five units, the average scores of the experimental group consistently exceeded those of the control group, suggesting that the learning model or environment for the experimental group was more favorable for fostering student learning transfer. Notably, in Unit 5, the experimental group's average score was 3.81 points higher than the control group's, highlighting a significant difference.

The standard deviation of the experimental group was highest in Unit 3, which may require further investigation into the learning methods or students' understanding of that unit.

The control group's mean score in Unit 3, 4 and 5 decreased, and the standard deviation was also relatively small, which may indicate that students generally encountered learning obstacles.

Figure 11 describes the trend of the horizontal transfer test results for the experimental and control groups over 5 units.

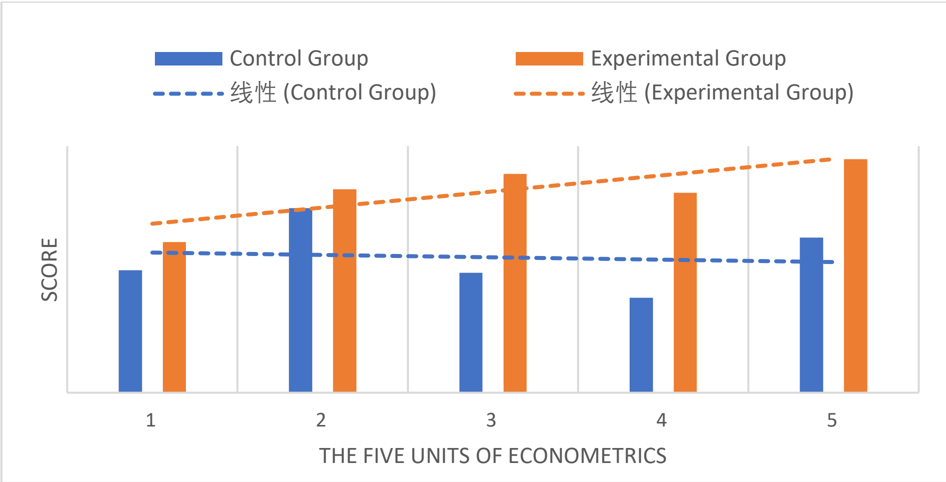

Figure 11 The Trend of Horizontal Transfer Test Scores over 5 Units

The mean scores of the experimental group showed an upward trend from Unit 1 to Unit 5, except for Unit 4, indicating that the performance of the experimental group students gradually improved as the teaching units progressed. The phenomenon in Unit 4 may be related to the more abstract and difficult content of Unit 4. Unit 4 also occupies the most class in the lesson plan.

The control group's mean scores did not show an upward trend, and the mean score for Unit 4 was lower than that of the experimental group, which may indicate that students encountered learning difficulties in that unit, and traditional teaching methods were not effective enough.

The research conducted Repeated Measures Analysis of Variance (Repeated Measures ANOVA). Table 11 presents the results of the Mauchly's test of sphericity.

Table 11 *Mauchly's Test of Sphericity*[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Squared	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
unit	.554	50.374	9	.000	.801	.844	.250

Table 11 shows the results of the sphericity test in "Mauchly's Test of Sphericity," with W=0.554, P value<0.001, which is less than 0.05, indicating the violation of the sphericity assumption. When the sphericity assumption is violated, the results of the multivariate analysis of variance should be taken as the standard and at the same time, the results of the corrected one-way analysis of variance can also be referred to.

Table 12 presents the results of the multivariate analysis of variance.

Table 12 *Multivariate Tests*[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
unit	Pillai's Trace	.261	7.401	4.000	84.000	.000
	Wilks' Lambda	.739	7.401	4.000	84.000	.000
	Hotelling's Trace	.352	7.401	4.000	84.000	.000
	Roy's Largest Root	.352	7.401	4.000	84.000	.000
unit * group	Pillai's Trace	.105	2.476	4.000	84.000	.050
	Wilks' Lambda	.895	2.476	4.000	84.000	.050
	Hotelling's Trace	.118	2.476	4.000	84.000	.050
	Roy's Largest Root	.118	2.476	4.000	84.000	.050

The results show that the main effect of the learning units is significant, F=7.401, p value < 0.001; the interaction effect between the learning units and the groups is not significant, F=2.476, p value = 0.05. The findings indicate that there are differences in scores across the units, but the effect of the group on the scores does not change with the variation of the units.

Table 13 presents the between-subject effect test, with P value< 0.001, indicating that there are differences in learning outcomes between the experimental group and the control group.

Table 13 *Tests of Between-Subjects Effects*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	869085.240	1	869085.240	12229.981	.000
group	1145.393	1	1145.393	16.118	.000
Error	6182.382	87	71.062		

Figure 12, which presents the estimated marginal means graph, depicts the variation in scores at five time points for both groups.

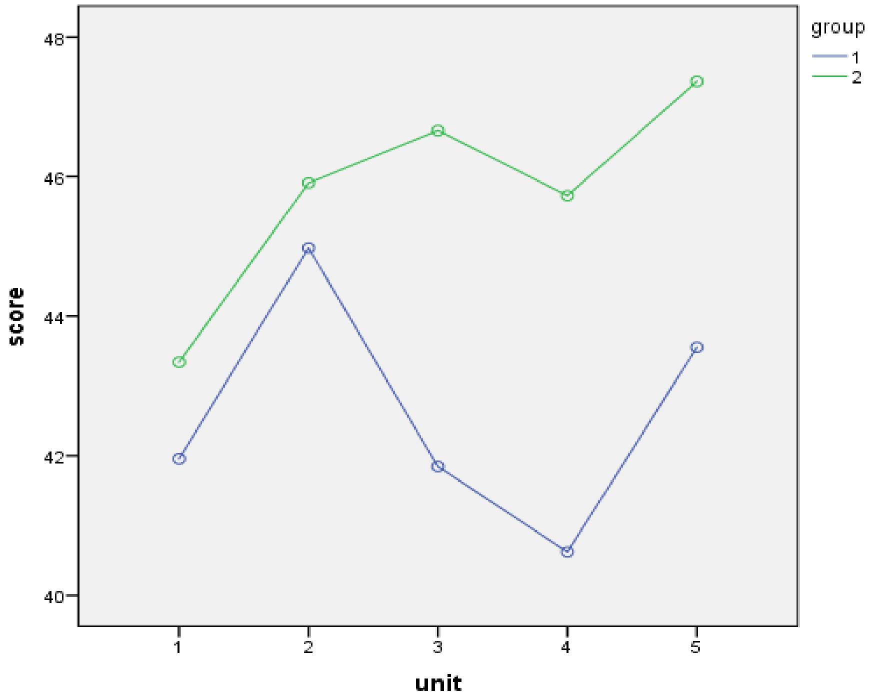

Figure 12 Estimated Marginal Means

The graph shows a significant difference in the score changes between the two groups. The control group's score changes are not regular, while the experimental group's scores, except for Unit 4, are gradually increasing.

(2) Vertical transfer test and analysis

Table 14 presents the descriptive statistics of the Vertical transfer test scores for students in the experimental and control groups across the 5 learning units.

Table 14 Descriptive Statistics of Vertical Transfer Test Scores for 5 Units

Test Time	Experimental Group Mean	Experimental Group SD	Control Group Mean	Control Group SD
Unit 1	33.40	3.97	32.00	3.85
Unit 2	35.40	3.42	32.91	4.19
Unit 3	36.09	5.12	30.00	4.10
Unit 4	35.36	5.37	28.55	4.16
Unit 5	36.57	4.60	31.26	4.02

In all 5 units, the mean scores of the experimental group were higher than those of the control group, which may indicate that the learning model and learning environment of the experimental group were more conducive to students' learning and transfer. The overall performance of the experimental group students was better than that of the control group, especially in Unit 5, where the experimental group's mean score was 5.31 points higher than that of the control group.

The standard deviation of the experimental group was highest in Unit 3, which may require further investigation into students' understanding of that unit.

The control group had the lowest score in Unit 4, with the largest standard deviation, which may indicate that this unit is a difficult point in the students' learning process.

Figure 13 describes the trend of the Vertical transfer test scores for the experimental and control groups over 5 units.

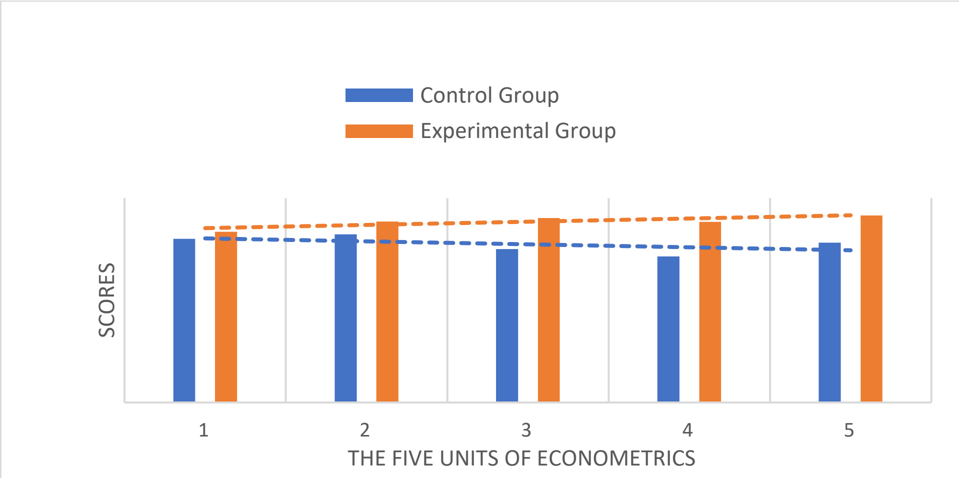

Figure 13 Trend of the Vertical Transfer Test Scores over 5 Units

The scores of the experimental group showed a gradually increasing trend, indicating that as the learning units increased, the performance of the experimental group students gradually improved. The average score increased from 33.40 in Unit 1 to 36.57 in Unit 5.

The control group's average scores did not show an upward trend from Unit 1 to Unit 5. There was a noticeable drop in the control group's scores in Unit 4, and then a slight recovery in Unit 5, but it did not reach the level of Unit 1.

The research conducted a Repeated Measures Analysis of Variance (Repeated Measures ANOVA)). Table 15 presents the results of the sphericity test.

Table 15 *Mauchly's Test of Sphericity*[a]

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilonb		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
unit	.555	50.291	9	.000	.765	.805	.250

Table 15 shows the results of the sphericity test in "Mauchly's Test of Sphericity," with W=0.555, P value<0.001, which is less than 0.05, indicating the violation of the sphericity assumption. When the sphericity assumption is violated, the results of the multivariate analysis of variance should be taken as the standard and at the same time, the results of the corrected one-way analysis of variance can also be referred to.

Table 16 presents the results of the multivariate analysis of variance.

Table 16 *Multivariate Tests*

Effect		Value	F	Hypothesis df	Error df	Sig.
unit	Pillai's Trace	.327	10.189	4.000	84.000	.000
	Wilks' Lambda	.673	10.189	4.000	84.000	.000
	Hotelling's Trace	.485	10.189	4.000	84.000	.000
	Roy's Largest Root	.485	10.189	4.000	84.000	.000
unit * group	Pillai's Trace	.208	5.515	4.000	84.000	.061
	Wilks' Lambda	.792	5.515	4.000	84.000	.061
	Hotelling's Trace	.263	5.515	4.000	84.000	.061
	Roy's Largest Root	.263	5.515	4.000	84.000	.061

The results show that the main effect of the learning units is significant, F=10.189, p value < 0.001; the interaction effect between the learning units and the groups is not significant, F=5.515, p value = 0.61. The findings indicate that there are differences in scores across the units, but the effect of the group on the scores does not change with the variation of the units.

Table 17 presents the between-subject effect test, with P value< 0.001, indicating that there are differences in learning outcomes between the experimental group and the control group.

Table 17 *Tests of Between-Subjects Effects*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	489177.813	1	489177.813	10657.369	.000
group	2174.640	1	2174.640	47.377	.000
Error	3993.337	87	45.900		

Figure 14, which presents the estimated marginal means graph, depicts the variation in scores at five time points for both groups.

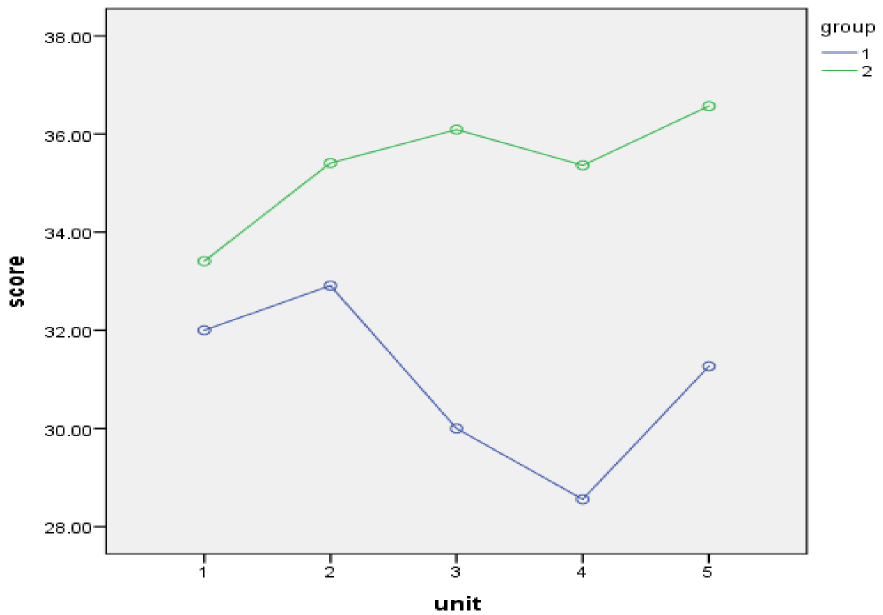

Figure 14 Estimated Marginal Means

The graph shows a significant difference in the score changes between the two groups. The control group's score changes are not regular, while the experimental group's scores, except for Unit 4, are gradually increasing. In Unit 4, both the experimental group and the control group experienced a decline in scores, which may indicate that the learning difficulty of this unit is relatively high. This can be seen from the substantial allocation of class time to this unit. Moreover, the decline in the control group's scores was much greater than that of the experimental group, suggesting that the teaching methods of the experimental group are effective.

2) self assessment

Based on the content of transfer of learning, determine the content of the students self-assessment to evaluate the effectiveness of implementing learning models.

This assessment covers 5 units, with each unit consisting of three parts of self-assessment: Knowledge Learning, Cognitive Strategy, and Metacognitive Strategy.

Five experts have assessed the rationality of the self-assessment forms for the 5 units(see appendix).

These self-assessment forms are distributed to students at the end of each unit and the collected data is analyzed.

Table 18 has compiled the average number of "Yes" answers from students for each unit, as well as the ratio of "Yes" answers to the total number of questions.

Table 18 *The Result of Self-Assessment Forms for 5 Units*

NUM	average number of "Yes" answers			proportion of "Yes" answers		
content	K	CS	MCS	K	CS	MCS
unit 1	5	3	3	0.56	0.33	0.33
unit 2	6	4	3	0.67	0.44	0.33
unit 3	5	3	3	0.83	0.50	0.50
unit 4	9	6	6	0.75	0.50	0.50
unit 5	7	5	6	0.78	0.56	0.67

Note: K means knowledge, CS means cognitive strategies, MCS means metacognitive strategies

Figure 15 presents the self-assessment trend for the students' mastery of knowledge, cognitive strategies, and metacognitive strategies across the five units.

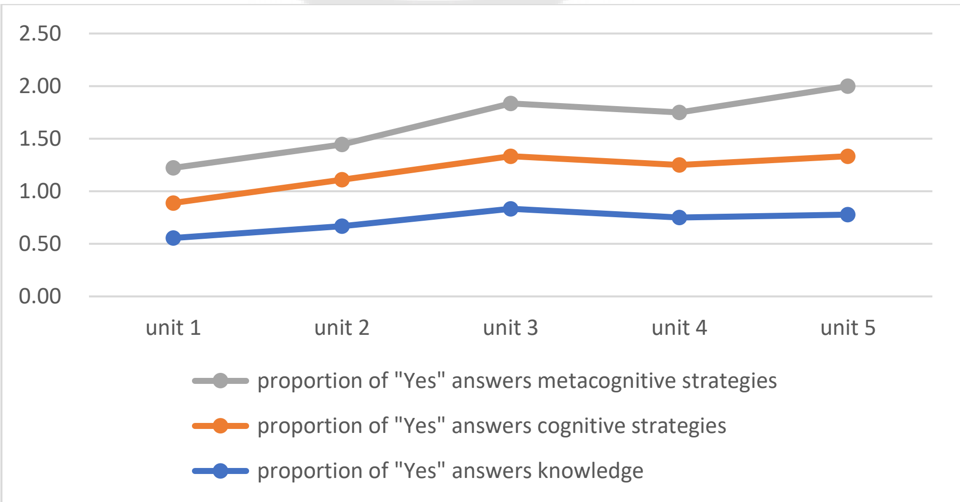

Figure 15 Self-Assessment Trend

The Self-Assessment Trend indicates that, overall, there is an upward trend in the students' grasp of knowledge, cognitive strategies, and metacognitive strategies as the units progress. However, there is a decline in Unit 4, which may be due to the higher difficulty of the learning content, as evidenced by the substantial class times allocated to this unit. Further exploration of the possible reasons will be conducted through student interviews.

4.3.2 Interview Results

1. Student Interview Results

Following the deployment of the spiral GRR learning model in the econometrics course, a random selection of five students from the experimental group was interviewed to explore and assess the impact of the learning model on their educational experience. The key points from these interviews are outlined below.

1) Students' Transfer of Learning in Econometrics Improved Through Spiral GRR Learning

Through the research and implementation of the Spiral GRR learning model in the econometrics classroom, students believed that it was a better learning experience than their previous classroom learning. The design of teaching content that gradually increased in complexity improved students' adaptability and deepened their understanding of the content step by step. They gained more learning activity experience during the learning process, gradually reduced their dependence on teachers, and improved their ability to learn independently. They learned more learning strategies, their learning engagement and enthusiasm increased, their cognitive flexibility was enhanced. They had better academic performance and were better able to apply what they learned to other experiences.

Students believe that compared with previous classroom learning experience, the Spiral GRR learning model provides a structured learning path. Students will transfer what have learned to the next unit, and they are very satisfied.

"In class, my learning process has become more organized and in-depth, and I think the new learning model has greatly promoted my learning transfer ability. By applying similar thinking and analysis skills in different learning units, I can master new concepts more quickly." (student 1)

Students believe that their learning motivation and skill have improved, and they are more confident in applying what they have learned to independent learning.

"The most impressive thing for me is that as I mastered the knowledge, the teacher gradually reduced direct guidance to us. This makes me feel more confident and encourages me to learn independently. At the same time, every time we come into contact with new content, we will review and integrate the knowledge learned before, which helps me build a complete knowledge framework." (Student 4)

The students' responses indicate that they have been able to transfer the learning strategies taught by the teacher to other situations.

"I usually list the key concepts and questions during the preview, and then actively seek answers in class. I will review immediately after class to consolidate the knowledge learned in class. At the same time, I will try to connect the newly learned concepts with the previous knowledge points to help me build a knowledge framework." (Student 5)

2) Students' Opinions on the Classroom

In the interview, students were encouraged to express their opinions on the implementation of the learning model. Most students indicated that through the teacher's introduction, they had gained an understanding of the Spiral GRR model and the teacher's intention in adopting it. Students believe that compared with the traditional classroom learning experience, the new classroom experience is more popular, the classroom interactivity is enhanced, and students are more adept at thinking and actively exploring.

"I feel that the learning atmosphere has become more active and inclusive. Students have more opportunities to practice and think, are more willing to share their views, and I feel my progress. I hope to have the opportunity to complete the learning process according to such a learning model in other classes. "(Student 1)

"In traditional classes, I often feel overwhelmed by a large amount of information in a short period of time. It is difficult to absorb and remember all the details in the lecture. Sometimes I feel that I can't keep up with the course progress. Now the classroom makes me an active learner, not just a passive recipient." (Student 2)"

3) What difficulties did you encounter when studying Unit 4?

Students said that the content of Unit 4 is obviously more complex, involving a lot of tests, such as heteroscedasticity and autocorrelation tests.

"Unit 4 feels more theoretical, requiring more statistical concepts to be memorized and understood. I found it difficult to master the test for multicollinearity during the study because it involves the relationships between many variables." (Student 1)

"I think there is more mathematical derivation in Unit 4, which requires a strong mathematical background to understand. When studying the model that relaxes assumptions, I am confused about how to interpret the test results." (Student 3)

"The content of Unit 4 is more in-depth, involving the classic assumptions in econometrics, which requires us to have a deeper understanding of the previous knowledge, and also involves the test methods and the principles behind them. This makes me feel difficult to understand." (Student 4)

2. Teacher classroom observation record results

After the learning model was implemented in econometrics, a content analysis was conducted based on the classroom observation records of 3 econometrics teachers. The 3 econometrics teachers here are the same group of teachers interviewed in the phase 1.

The main recorded content is summarized as follows:

1) Teachers' teaching

"Teachers used "problem-oriented learning," encouraging students to raise questions and find answers independently. This method stimulated students' curiosity and desire to explore, promoting horizontal knowledge transfer. In addition, teachers also applied "case studies" to let students apply theoretical knowledge to practical situations, which helps achieve vertical transfer. Encouraging students to reflect on themselves, this strategy helps students adjust their learning strategies in time and improve learning effectiveness. "(Teacher A)

"The teacher used visual tools such as "concept maps" and "mind maps" to help students organize and integrate knowledge. This method promotes the development of students' cognitive structures and aids in learning transfer. The teacher used "cooperative learning strategies, allowing students to discuss and solve problems in groups, and this interaction promotes knowledge sharing and in-depth understanding."(Teacher B)

2) Students' learning

"The students' participation in the classroom was quite high. They actively asked questions, participated in group discussions, and actively sought feedback from teachers. Their overall performance was also excellent; students could clearly explain concepts and apply them to practical cases. This positive learning attitude and ability indicate that the Spiral GRR model effectively stimulated students' interest and participation in learning." (Teacher A)

"The overall performance of the students was also satisfactory. Compared with the traditional classroom learning process, I observed that the students were more engaged and showed a strong interest in the learning content. They were able to

demonstrate a deep understanding of the course material and effectively apply the knowledge learned in group activities." (Teacher C)

3. Results of effectiveness evaluation

After the learning model was researched and implemented in the econometrics course, students' learning transfer was enhanced, including their performance in applying what they have learned to solve problems—vertical transfer, and their performance in previewing and learning new content—horizontal transfer. Students showed enthusiasm, autonomy, and adaptability in their classroom learning. They consciously transferred what they learned to other learning experiences. From this, it can be concluded that the Spiral GRR learning model and its implementation is effective.

CHAPTER 5
CONCLUSION AND DISCUSSION

5.1 Brief Summary of the Study

1. Research Objectives

1) To research the definition and contents of transfer of learning, and problem situation for college students;

2) To develop a learning model that integrates spiral structure, GRR model, and strategic learning, with the aim of enhancing college students' learning transfer ability;

3) To assess the effectiveness of the spiral GRR learning model in improving college students' learning transfer ability following its implementation in econometrics course.

2. Research conclusions

1) To research the definition and contents of transfer of learning, and problem situation for college students

Through literature review, the research clarified the definition and content of transfer of learning. The definition of transfer of learning involves two aspects: horizontal transfer and vertical transfer, which lays the foundation for measuring the effectiveness of learning models in promoting transfer in the classroom. Combining literature review with interviews of students and teachers, the research understood the importance of transfer of learning, the necessity of transfer in econometrics and the difficulties and issues existing in students' learning transfer.

2) To develop a learning model that integrates spiral structure, GRR model, and strategic learning, with the aim of enhancing college students' transfer of learning

This research initially conducted a comprehensive review of the Knowledge Spiral Theory. The theory provides learners with a macro learning path but has obvious shortcomings in in-depth analysis and guidance for specific learning stages. Furthermore, this study examined the GRR model and learning strategies that promote learning transfer. They can elaborate in detail the specific actions and strategies that learners should adopt at various stages.

This research not only draws on the macro guidance of the Knowledge Spiral Theory but also integrates effective strategies of the GRR model at specific learning stages. More crucially, the study introduces the concept of strategic learning and combines it with constructivist theory to promote learners' active exploration and meaning construction at different learning stages.

Through this integration, this research developed a brand-new model to promote transfer of learning, the Spiral GRR, through seven steps. The model, based on an in-depth analysis of the Knowledge Spiral Theory, further absorbs the essence of the GRR model and combines it with strategic learning, incorporating the core concepts of constructivist theory. The Spiral GRR model emphasizes the learners' subjectivity in the knowledge construction process, encouraging them to flexibly apply and adjust learning strategies when facing new learning situations to achieve effective knowledge transfer. After evaluation by experts, some specific content in parts of the learning model was modified.

3) To assess the effectiveness of the spiral GRR learning model in improving college students' transfer of learning following its implementation in econometrics course

To verify the effectiveness of the new model, this research implemented the model in an econometrics classroom. Through carefully designed teaching activities and assessment tools, we systematically measured and analyzed the effects of the model's implementation. The research results show that.

(1) In both horizontal and vertical transfer tests, the new model has a significant positive impact on promoting students' learning transfer.

(2) Through students' self-assessment of learning transfer in knowledge, cognitive strategies, and metacognitive strategies, the effectiveness of students' transfer of specific content was understood and presented.

(3) The collection of interviews with students and teachers' classroom observation records found that the new model not only improved their learning effectiveness in the econometrics course but also enhanced their adaptability and innovative thinking when facing new problems.

(4) Additionally, for more difficult learning units, although the new model did not show a continuous improvement in performance, compared with traditional learning methods, the new model only showed a slight decline in performance or even maintained previous learning performance.

5.2 Discussion of the Results

5.2.1 Discussion of the definition and contents of transfer of learning

This study aims to enhance students' learning transfer for problem-solving based on the GRR model in the course of Econometrics. The exploration and understanding of the teaching background is an important prerequisite for instructional teaching, including the discovery of the importance of learning transfer ability, the development needs of students' learning transfer and problem-solving ability, and the strong applicability of the course. These views not only come from the observation of real teaching practice but are also consistent with relevant literature. The "Implementation Opinions on Deepening the Reform of Innovation and Entrepreneurship Education in Colleges and Universities" emphasizes the qualities and abilities that college students should have in innovation and entrepreneurship, including learning transfer ability and problem-solving ability. UNESCO's "Education 2030 Action Framework" also emphasizes the importance of cultivating learning transfer ability and problem-solving ability, and regards it as one of the directions for future education reform and development. Learning transfer activities are the advanced output of knowledge and experience, together with learning understanding and application practice, forming the three elements of subject ability, enabling individuals to successfully complete specific subject cognitive activities and problem-solving tasks. However, under the current course and teaching conditions, students' learning understanding ability in the corresponding subject courses is relatively good, the application practice ability needs to be improved, and the transfer innovation ability is at a lower level (Wang, 2016). Transfer is especially important and very often the kinds of transfer hoped for do not occur (Perkins & Salomon, 1992).

The purpose of this study is to develop students' learning transfer ability oriented towards problem-solving. Rebello, el ta,. (2017) pointed out in their research that learners applied different types of transfer processes when solving problems. Schwartz, Bransford and Sears (2005) further compared the concepts of "efficiency" and "innovation" in transfer in their 2005 research. They believe that "efficiency" refers to the ability of learners to quickly recall and apply knowledge in new situations, and cultivating learners' "efficiency" in problem-solving is similar to "horizontal" transfer; while "innovation" refers to their ability to rethink or reorganize the problem situation, making it easier to handle than before, and "innovation" is similar to "vertical" transfer. Professor Hu Weiping(2020), a Chinese expert in curriculum and teaching theory, also pointed out that problem-solving is an application of transfer, that is, applying the knowledge learned to solve problems under different conditions. Cognitive psychology has discovered and then attached importance to the role of transfer from the study of problem-solving.

Although many literatures have studied the effects of other methods, such as STEM and PBL, on improving transfer ability and problem-solving ability (Cordiero & Campbell, 1996; Granado-Alcon, el ta.,2020; Salikha, Sholihin & Winarno, 2021; Yu & Hu, 2015), the core of GRR is to transfer metacognition from teachers to students, and metacognition is very important for learning transfer. The views of this paper are consistent with many research results, and Leberman & McDonald (2016) found in their research that Metacognition, which is, being aware of one's own thinking and learning processes, is required to adapt existing schemas to new situations. When learners can modify schemas, that is, they can connect relevant existing learning with new situations, positive transfer will occur. Complex transfer largely depends on metacognitive skills, requiring learners' creativity, adaptability, and innovative thinking. In addition, transfer cannot be separated from the concepts of intention (Salomon & Globerson, 1987), reflection (Macaulay & Cree, 1999), and metacognition (Charff, el ta.,2017; Kudesia, 2019; Jankowski & Holas, 2014; Di Giovanni, 2016) also pointed out that the gradual release of responsibility model is further enhanced with mindfulness practices, and McVee et al. (2018)showed that the GRR teaching model supports students' learning and reflection. Therefore, using GRR teaching, integrating elements such as metacognitive transfer, mindfulness practice, and reflection practice, which are indispensable for transfer, into teaching activities, promotes students' successful transfer. At the same time, Professor Hu Weiping emphasized that in order to achieve application transfer, students should break through negative thinking patterns, otherwise it is difficult to achieve transfer. In GRR, teachers vocalize the thinking process and pass it on to students, teaching students to think independently and actively, and to produce mindfulness, which is key to learning transfer. Reviewing the above research, the GRR teaching method is effective.

In this study, the GRR teaching model is applied to the course of Econometrics, based on the Cognitive Thinking Hierarchy Theory, gradually transferring declarative knowledge, procedural knowledge, and metacognitive regulation to students. This study considers metacognition as a strategic knowledge(Pressley, Borkowski & Schneider, 1987). The research is consistent with the views of this study, also indicating that metacognition belongs to a special strategic knowledge, and the acquisition process of metacognition takes other cognitive processes, such as strategies, as input, and produces additional information about the important attributes of strategies.

Wang (2016) showed in his research that declarative knowledge is the basis of the orientation regulation mechanism, and activity experience, that is, procedural and strategic knowledge, is the basis of the execution regulation mechanism. The two psychological regulation mechanisms work together to ensure that individuals can successfully complete specific subject cognitive activities and problem-solving tasks.

This study applies the GRR teaching model to the course of Econometrics, believing that Econometrics, as a quantitative analysis tool, has good transferability in its methods. This view is consistent with the research of McKee & Orlov (2021), Zapata and Mukhopadhyay (2022).

5.2.2 Discussion of the results of developing learning model

Firstly, the econometric teaching design in this study is based on the Spiral GRR model. The application of GRR to enhance students' problem-solving learning transfer has been discussed above. In this study, the basic GRR model has been spirally transformed based on cognitive hierarchy theory and spiral theory, with three cycles of teaching involving different content, including declarative knowledge, procedural knowledge, and metacognitive regulation. Essentially, it is the exposure to the same knowledge in different forms, with students' exposure to a given area of content at a gradually increasing level of difficulty, corresponding to the gradual enhancement of their abilities. The findings of this research align with those of Harden (1999), who identified that spiral curricula possess distinct attributes: subjects are revisited in a cyclic manner, challenges escalate in complexity, new material is connected to prior knowledge, and students' proficiency advances. The strength of a spiral curriculum is rooted in its pursuit of advanced objectives. It is not merely about revisiting topics; instead, it involves deepening understanding, with each subsequent interaction enhancing the previous one. Within this framework, students are motivated to progress from rote memorization to the practical application of their knowledge and skills.

Secondly, this study developed teaching principles aimed at developing students' learning transfer capabilities. The teaching principles include: using different teaching methods for different types of knowledge; emphasizing teacher guidance in early teaching; embracing and bridging strategies to promote learning transfer; and the application of case-based teaching and project-based teaching methods. These principles are derived from literature related to teaching strategies for developing learning transfer capabilities. Studies by Li (2016) and Xu (2001) have shown that each type of knowledge has its own learning process and corresponds to different teaching strategies. Kurniawati et al. (2017) pointed out that declarative knowledge pertains to information regarding facts and data, while procedural knowledge pertains to the understanding of how to execute different cognitive tasks. Ranta and Lyster (2007) highlighted that explicit knowledge is directly absorbed from observation and teaching; the development of skills hinges on converting this knowledge into procedural knowledge in the form of production rules; and such rules are acquired solely through active practice.

In early teaching, teacher guidance plays a very important role. This study's results are consistent with the research by He(2002), which found that the role of teacher guidance is indispensable, to build a conceptual framework for students, that is, to establish scaffolding in the learning process, and to guide them to use this framework to understand and solve problems. Perkins and Salomon (1996b) distinguish between automatic and mindful transfer through the concepts of 'low road' and 'high road' transfer, suggesting that distinct instructional strategies are necessary for each. Leberman and McDonald (2016), in their examination of these transfer types, noted that automatic transfer, over time and with practice, can expand along the low road. Conversely, mindful high road transfer is intentional, involving deliberate thought and cognitive effort, and typically occurs when there are substantial discrepancies between the initial learning context and the transfer context. Low road transfer is facilitated by strategies that closely align learning with the transfer situation, often referred to as 'hugging' strategies. High road transfer is more likely in situations where learners have been guided to create bridges to different contexts, and it is essential for students to learn how to construct these bridges independently, as teachers may not always be present to facilitate.

Thirdly, in the teaching design of this study, a progressive set of objectives from declarative knowledge, procedural knowledge, to metacognitive awareness was established, ultimately achieving learning transfer in problem-solving. The sequence of objectives is consistent with the teaching Spiral GRR model, the teaching process, and even the assessment.

Specifically, first, the teaching enables students to master declarative knowledge by autonomously constructing a network structure in the brain, that is, the schema. This view is consistent with the research by Pi and Cai (2000), which emphasizes that "modern cognitive psychology emphasizes declarative knowledge as the knowledge that forms a network structure and integrates, rather than the unchanged knowledge memory and recall as stated in Bloom's taxonomy." Secondly, the teaching enables students to master the declarative form of procedural knowledge, clarify the conditions for the application of procedural knowledge, and achieve the transformation from declarative knowledge to procedural knowledge, thus achieving the purpose of mastering procedural knowledge. This view is consistent with the research by Yang(2010). Moreover, the learning of the above knowledge is accompanied by the learning purpose of cognitive strategies, as the research by Pi Liansheng, Pi and Cai (2000)indicates that cognitive strategies generally cannot be taught and learned separately from declarative knowledge and intellectual skills.Thirdly, Verschaffel et al. (2009), Li Jian, Zhang Houcan (2006), and Desoete & Roeyers (2002) have shown in their research that strategies are an important processing object of metacognition, and the selection of regulatory strategies is one of the important mechanisms of metacognition. Therefore, the purpose of this stage of teaching is to cultivate students' metacognitive awareness, so that students can choose and apply appropriate strategies to organize existing knowledge, extract common elements between new and old situations, establish connections, and regulate strategies to re-represent problems, plan, and organize problem-solving solutions. This is consistent with the research by Liu et al. (2011), which believes that different materials and different environments require different strategies, and students need to master metacognitive knowledge to coordinate and control learning activities to achieve the best adaptability.Fourth, Implementing problem-solving solutions. Step by step, the ultimate goal of learning transfer is achieved. This goal design is consistent with the research.

Fourth, Selection of Teaching Content. The teaching content selected in this study is econometrics, which has an extremely important position as the basic methodology of modern economic research. As Hong Yongmiao (2007) pointed out in his research, many people believe that econometrics is just a technical analysis tool for empirical research in economics, without realizing the importance of econometrics as the basic methodology of economic research. Basic methodology has a high degree of transferability, which is consistent with the ultimate goal of this study. Teaching this course with the GRR teaching model enables students to master transferability not only in the basic methods obtained in the problem-solving process but more importantly in.

5.2.3 Discussion of the effectiveness of the learning model in improving college students' learning transfer ability

The teaching implementation phase involved researchers using the GRR teaching mode and the traditional teaching mode to teach two classes in econometrics during the spring semester of 2024. This implementation aimed to assess the effectiveness of the GRR teaching mode.

In the teaching process based on the GRR mode, special emphasis was placed on exercising students' use of cognitive strategies to learn various types of knowledge, as well as fostering students' metacognitive awareness and cultivating their habit of reflecting on the process of learning and thinking. The research results indicate that students in the GRR mode class exhibited higher levels of learning transfer and problem-solving abilities compared to the traditional teaching class. This is consistent with the research perspective of Liu(2002), who argued that students must engage in metacognitive reflection, abstracting professional knowledge, problem-solving strategies, and learning strategies from previous problem-solving, and then utilize other variant problems to facilitate flexible knowledge transfer. Scharff et al. (2017) discovered a positive correlation between metacognition, which involves intentional awareness and the application of that awareness, and learning transfer. Their study, which surveyed 74 faculty members and 118 students across five universities in Australia, Belgium, the United Kingdom, and the United States, indicated that there is a significant positive correlation between thinking about transfer and the consideration of the learning process in relation to the potential use of metacognitive awareness to guide practice. The research results of Hollingworth & McLoughlin (2001) are also consistent, indicating that applying, discussing, and reflecting on many of the same ideas across different topics and different problems within topics can help transfer the developed skills to broader application *area*s. Educational research affirms the pedagogy and teaching methods that emphasize the interaction of cognitive, metacognitive, and emotional components of learning. If higher education practitioners only emphasize content and discrete skills, students may not develop deep learning methods that can transfer skills and knowledge to real-world contexts(Mayer, 1998).

During the implementation of the GRR-based teaching, the following teaching techniques were employed: direct teaching by the teacher, scaffolding initiated within the students' zone of proximal development, guiding students' autonomous construction, fostering collaboration, and providing opportunities for independent practice. Margolis, A. A. (2020) suggests that teachers scaffold with the aim of developing students' independent action by providing necessary support adapted to individual performance levels, rather than directly transmitting information to students for them to memorize and replicate, thereby facilitating the interaction between teachers and students to build new knowledge together. Aryal and Zollman (2007) carried out instructional interviews with nine student groups participating in an introductory physics course that was based on algebra. The course comprised both a learning phase and a transfer phase. Compared to students participating individually in a series of similar activities, students who were required to write down their answers before and after group discussions demonstrated better transfer performance. The research results indicate that group learning and peer scaffolding are important, as peers are effective in activating and challenging each other's conceptual resources and promoting learning transfer. In terms of independent practice, the teaching activities in this study were designed with diverse cases, projects, and literature tasks to enhance future transfer performance. The perspective of this study aligns with Holladay, & Quiñones (2003), who found that variability in practice can enhance training transfer, and self-efficacy generality mediates between practice variability and far transfer.

Schmidt & Bjork (1992) found that combinations of random variable practice led to unfavorable training performance but suggested that research results indicating random variable practice enhances transfer performance are more compelling.

5.3 Recommendations for Future Studies

In this study, the following suggestions are considered useful for guiding further research.

Firstly, details of applying modern educational technology means should be added to the instruction design, such as how to use the learning management system to pay attention to all students' questions in a timely manner, use intelligent systems to reply to some frequently asked questions, and provide some repeated but necessary prompts in each class, so as to reduce the teacher's repeated answers, save class time and improve teaching efficiency. Meanwhile, an offline question and answer system is established.

Secondly, details of teachers' guidance content and wording, as well as the details of organizing activities, are described in teaching activities, so that teachers can better understand how to provide clues to students to guide them to focus on key points and think actively.

Thidly, continuous evaluation: Regularly assess the teaching effectiveness of GRR, and collect feedback from students, colleagues, and oneself. Timely adjustment: Adjust teaching strategies and methods in a timely manner based on the evaluation results to continuously improve teaching quality.

Fourth, explore the application and effectiveness of the GRR teaching model in other types of courses and accumulate more empirical test data.

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APPENDIX

APPENDIX A

Interview Approval by Zhanjiang University of Science and Technology:

From the Dean of the School of Economics and Finance: *" We fully support this interview project. Understanding the real experiences of students and teachers is crucial for us to improve curriculum settings and teaching methods. The school will provide the necessary resources and support to ensure the smooth progress of the project. We believe that through this positive feedback loop, we can further enhance our teaching effectiveness and students' learning outcomes."*

From the Head of the Economics Program: *"I completely agree with the Dean's point of view. As the head of the program, I believe that deeply understanding the needs and challenges of students and teachers is key to our continuous progress. We will work closely with teachers and students to ensure that the interview project can fully collect feedback and transform it into practical teaching improvement measures. In addition, we will also encourage teachers to adopt innovative teaching methods to meet the different learning styles and needs of students."*

INTERVIEW WITH STUDENTS

Interview Topic: Students' Experiences and Feedback on Learning Econometrics

Interview Subjects: 15 students, divided into 3 groups, with 5 students per group

Interview Format: Informal group discussion

Interview Questions:

1. Recognition of Applied Value:

"Do you think Econometrics has applied value in academic research? Can you give examples of how you have used the knowledge of Econometrics in previous application scenarios?"

2. Discussion on Learning Challenges:

"What is the biggest challenge you have encountered in your course study?"

3. Evaluation of Teaching Links:

"Looking back on your learning experience, which part of the teaching process do you think has been the most helpful to you?"

We are very grateful for the insights and experiences you have shared today. Your opinions are crucial for us to improve teaching methods and course content. If you have any other ideas or suggestions, please feel free to share them with us at any time.

Interview Records:

Question 1:

"*We believe that Econometrics is very valuable in academic research. For example, in my course project on market analysis, I used econometric models to predict consumer behavior.*"

"Econometrics is very useful for understanding economic phenomena and making predictions. I applied econometric methods in my thesis to analyze the impact of economic policies."

"Econometrics is very important in academic research, especially when conducting empirical analysis. I applied these skills in a research assistant position to analyze economic data."

Question 2:

"For me, the biggest challenge is understanding the assumptions of different models. In practice, I often don't know which model to choose."

"The main challenge I encountered when learning Econometrics was the complexity of software operations. Mastering how to use statistical software for data analysis took me a lot of time."

"I find the mathematical derivations in Econometrics very difficult to understand. This leads to a lack of confidence when applying models."

Question 3:

"I think the practical exercises in class are very helpful, especially when the teacher demonstrates how to solve problems step by step."

"I think the group discussion session is very effective because it allows us to share different perspectives and problem-solving methods."

"I think the case study session is the most helpful. By analyzing real economic data, I was able to understand the application of Econometrics more deeply. The reflective writing tasks assigned by the teacher also greatly helped me. This learning

strategy gave me the opportunity to review and think about my learning process in the course, identify my strengths and areas for improvement."

INTERVIEW WITH TEACHERS

Interview Topic: The Learning and Transfer of Applied Abilities in Economics Major Students

Interview Subjects: Three economics major teachers

Interview Purpose: To understand the transfer performance of students after course learning, potential influencing factors, and the measurement methods of learning transfer ability.

Interview Questions:

1. Learning Transfer Performance

"In your teaching experience, how do you observe the performance of students' learning transfer between different course units? Specific examples?"

2. Potential Influencing Factors

"What factors do you think may hinder students from effectively transferring learning in the course?"

3. Measurement of Learning Transfer:

"How do you evaluate and measure students' transfer ability in the same course learning?"

Thank you very much for sharing your valuable opinions and experiences today. Your insights are of great significance for us to improve teaching methods and course design. We look forward to continuing to work with you to jointly enhance students' learning and transfer abilities in economics.

Interview Records:

Question 1:

"Students' learning transfer between course units is usually influenced by their in-depth understanding of knowledge. Those students who can deeply understand the concepts tend to do better in transfer. For example, students who understand the principles of economics can more easily apply these principles to different economic models."

"I have observed that students' performance in learning transfer between different course units varies, with the use of cognitive strategies being a key factor. For example, some students can use comparison and contrast strategies to connect the concepts of different units, while other students have difficulty with this integration."

"In my experience, students perform better in knowledge transfer when they use cognitive strategies such as induction and deduction. A specific example includes students applying statistical methods learned in one unit to data interpretation in another unit."

Question 2:

"The different levels of metacognitive development among students may affect their transfer ability. I help them overcome transfer barriers by encouraging them to monitor their own understanding and reflect on the learning process."

"One of the challenges I observe students facing when transferring knowledge is that their grasp of the content previously learned is not deep enough, which limits their ability to apply this knowledge. This is usually related to a lack of effective memory and comprehension strategies."

"The obstacles to students' knowledge transfer in course learning may include insufficient adaptability to new situations, which is related to their cognitive flexibility and creative thinking strategies."

Question 3:

"I usually assess students' transfer ability through project assignments. I observe how they apply a concept to different situations."

"I include questions or activities in the pre-study tasks to let students demonstrate how they apply prior knowledge to new learning content. Or through self-study tests to assess students' knowledge retention and transfer ability."

"I organize classroom discussions: In classroom discussions, I guide students to connect the concepts of different units and assess whether they can apply knowledge learned earlier to new topics. I also ask students to reflect on themselves to understand how they perceive their own learning transfer."

APPENDIX B

1. Learning Topic: Unit 3 Dummy Variable Model

2. Learning Objectives:

Overall Objective: Students should be able to apply and adjust the dummy variable concepts, methods, and strategies learned in new learning experiences.

Sub-objective 1: Mastery of Dummy Variable Knowledge

1.1: Understand the definition and function of dummy variables, and be able to identify when and why to use dummy variables in regression models.

1.2: Master different types of dummy variable encoding methods, including 0/1 encoding and effects coding, and understand their applicable scenarios.

1.3: Be able to correctly apply dummy variables in regression models and explain their impact on model results.

Sub-objective 2: Development of Cognitive Strategies

2.1: Learn to apply dummy variables in different economic contexts through situational simulation, enhancing situational awareness.

2.2: Deepen the understanding of the differences between dummy variable models and ordinary regression models through comparative learning, fostering critical thinking.

2.3: Enhance understanding of dummy variable encoding and application through practical operations, improving practical skills.

Sub-objective 3: Cultivation of Metacognitive Skills

3.1: Learn to monitor one's learning progress and depth of understanding, developing self-assessment abilities.

3.2: Be able to promptly identify and correct errors in practice, improving self-correction abilities.

3.3: Reflect on the applicability and limitations of the dummy variable model, cultivating the ability to reflect and adjust strategies.

3. Learning Content: The book by Li Zinai is used, the syllabus, this study reorganizes the learning content by combining cognitive strategies and metacognitive strategies.

Unit 3 Dummy Variable Model (6 classes)

1) Knowledge Learning

---- Definition and function of dummy variables

---- Different types of dummy variable encoding methods

---- Application and interpretation of dummy variables in regression models

2) Cognitive Strategies

---- Situational simulation: Teach the application of dummy variables by simulating different economic situations.

---- Comparative learning: Compare the dummy variable model with the ordinary regression model to deepen the understanding of differences.

---- Practical operation: Deepen the understanding of dummy variable encoding and application through practical operation of data.

3) Metacognitive Strategies

---- Learning monitoring: Teach students how to monitor their own learning progress and depth of understanding.

---- Error identification: Encourage students to identify and correct errors in practice promptly.

---- Application reflection: Reflect on the applicability and limitations of the dummy variable model after its application.

4. Learning Context Analysis:

1) Whether the classroom layout is conducive to group discussions and individual work

2) The required statistical software and data resources are accessible to students for practical operations.

3) Collect students' prior knowledge levels of basic concepts, regression analysis methods, and dummy variables based on the results of pre-study tasks. Assess students' prior knowledge to determine the key and difficult points of this unit.

5. Learning Key and Difficult Point Analysis:

Teaching Focus:

1) The definition and function of dummy variables;

2) The encoding methods of dummy variables;

3) The application of dummy variables in regression models;

4) The establishment of models and analysis of results;

5) Acquisition of effective learning strategies, such as refinement, organization, categorization, etc.;

6) Development of metacognitive skills

Learning Difficulties:

1) Dummy variables and model selection:

2) Multiple collinearity issues:

3) Operation of statistical software:

4) Interpretation and verification of results:

5) Application of learning strategies:

6) Cultivation of metacognitive skills:

6. Leaning Activities and Time Allocation

Phase 1: Knowledge Learning (Dummy Variable Knowledge) (2 classes)

1) Guided Instruction

- **Teacher's Activities**: Select an economic dataset involving different regional sales data, for example, a dataset containing car sales volumes in various provinces, including a categorical variable indicating the province.

- **Students' Activities**: Observe how the teacher creates dummy variables for the province (e.g., whether it is a first-tier city), how to introduce these variables into the regression model, and explain the model coefficients.

2) Collaborative Learning

- **Teacher's Activities**: Divide students into groups, each group assigned different economic situation datasets, such as market penetration rates in different industries, sales data in different time periods, etc.

- **Students' Activities**: Each group discusses and decides how to create dummy variables for the categorical variables in the dataset and analyzes their impact on the model.

3) Independent Learning

- **Teacher's Activities**: Ask students to independently select an economic dataset involving categorical variables, such as a dataset on the impact of education level on wages.

- **Students' Activities**: Independently complete the exploration of the dataset, the creation of dummy variables, the construction of the regression model, and the interpretation of the results.

Phase 2: Cognitive Strategy Learning (2 classes)

1) Direct Instruction

- **Teacher's Activities**: Demonstrate how to use situational simulation to analyze product demand under different market conditions, such as simulating demand changes by changing prices or promotional activities.

- **Students' Activities**: Learn how to simulate different market conditions by changing dummy variables and observe their impact on demand forecasting.

2) Guided Instruction

- **Teacher's Activities**: Design a situational simulation activity, such as simulating the impact of a new product launch on the demand for existing products, and guide students to use dummy variables to distinguish product types.

- **Students' Activities**: In the simulated situation, apply dummy variables to analyze the impact of new products on the market.

3) Collaborative Learning

- **Teacher's Activities**: Organize group discussions, let students share how they use dummy variables to simulate product demand under different market conditions, and compare the effectiveness of different strategies.

- **Students' Activities**: Discuss their analysis results, jointly explore the applicability of dummy variables in different situations.

Phase 3: Metacognitive Development (2 classes)

1) Direct Instruction

- **Teacher's Activities**: Introduce metacognitive strategies, such as learning monitoring (tracking one's own learning progress), error identification (checking data encoding errors in regression analysis), application reflection (evaluating the applicability of the dummy variable model).

- **Students' Activities**: Learn how to apply these metacognitive strategies in the learning process through examples provided by the teacher.

2) Guided Instruction

- **Teacher's Activities**: Demonstrate how to use learning logs to monitor learning progress and identify errors in regression models, for example, checking whether dummy variables are correctly encoded.

- **Students' Activities**: Practice using learning logs to record their learning process, identify and correct errors in dummy variable modeling.

3) Collaborative Learning

- **Teacher's Activities**: Organize group reflection sessions, let students share their learning experiences in the process of dummy variable modeling, discuss difficulties and solutions.

- **Students' Activities**: Exchange learning experiences with peers, provide feedback to each other, and jointly explore how to improve learning strategies.

4) Independent Learning

- **Teacher's Activities**: Encourage students to conduct self-assessment, reflect on the effectiveness of learning strategies, and the applicability and limitations of the dummy variable model.

- **Students' Activities**: Independently write a learning reflection report, assess their learning process, including knowledge understanding, skill mastery, and strategy application.

7. Learning Summary

1) Knowledge Mastery:

- Students should have understood the definition, function, and application of dummy variables in regression models.

- Students have mastered different types of dummy variable encoding methods and can correctly apply them in actual datasets.

2) Cognitive Strategies:

- Through cognitive strategies such as situational simulation, comparative learning, and practical operations, students have deepened their understanding of dummy variables.

- Students have learned how to apply theoretical knowledge to different economic situations and can explain its impact on model results.

3) Metacognitive Development:

- Students have developed the ability to self-monitor, identify errors, and reflect, which helps them become more independent learners.

- Students have learned how to assess their learning progress and the effectiveness of strategies, and can make adjustments as needed.

- Students can apply the dummy variable model in new situations, apply the learned strategy experience and metacognitive strategies, demonstrating good learning transfer ability.

8. Learning Reflection

1) Good Aspects:

(1) The effectiveness of situational simulation**: By designing realistic situational simulation activities, students can more intuitively understand the application of dummy variables under different market conditions. For example, simulating the impact of a new product launch on existing product demand, students can clearly see how dummy variables help distinguish product types and analyze their impact on the market.

(2) Active student participation**: In group discussions and collaborative learning sessions, students show a high level of participation and interest. Students actively discuss different encoding methods of dummy variables and jointly decide on the best encoding strategy within the group.

(3) Use of technical tools**: Using statistical software for practical operations with dummy variables allows students to intuitively see data changes and model outputs, deepening their understanding and application of theoretical knowledge.

2) Existing Problems:

(1) Time management**: In some classroom activities, the allocation of time is not reasonable enough, causing some students to feel pressed for time during independent exercises and unable to complete them fully.

(2) Feedback mechanism**: Although formative assessments were provided, student feedback indicates that they hope to receive more specific and timely feedback to help them better understand errors and improve.

3) Improvement Measures:

(1) Optimize time allocation**: Re-plan the time allocation of classroom activities to ensure that each link has enough time for in-depth discussion and practice, especially the independent exercise part.

(2) Enhance the feedback mechanism**: Establish a more effective feedback system, including immediate verbal feedback, written feedback, and peer evaluation. Ensure that students can understand their performance in a timely manner and make adjustments based on the feedback.

APPENDIX C

Five experts: Two instructional design experts, one evaluation expert, one Econometrics subject expert, and one Econometrics teacher.

Expert	Department	Title
Mrs.Lin.	School of Education Zhanjiang University of Science and Technology	Professor
Mrs.Yang.	School of Education Zhanjiang University of Science and Technology	Professor
Mr. Zhang.	School of Education Zhanjiang University of Science and Technology	Professor
Mr. Zhou .	School of Economics and Finance Zhanjiang University of Science and Technology	Associate Professor
Mrs. Xiao.	School of Economics and Finance Zhanjiang University of Science and Technology	Professor

APPENDIX D

The test section includes horizontal and vertical tests for 5 units, as well as grading criteria. Here, only the test and grading criteria for Unit 3, the Dummy Variable Model, is displayed.

1. Horizontal test(Pre-study Task Test) and grading criteria:

Unit 3

Exam Name: "Regression Models Relaxing Basic Assumptions Pre-study Task Exam"

Total Score of the Exam: 50 points

Exam Content and Grading Criteria:

Short Answer Questions (Total 50 points, 10 points per question)

Question 1: Outline the basic assumptions of the classical linear regression model and their importance in economic data analysis.

Grading Criteria:

• 0-2 points: Did not outline basic assumptions or did not explain their importance.

• 3-5 points: Outlined basic assumptions but missed key points or the explanation of their importance was insufficient.

• 6-10 points: Comprehensively outlined the basic assumptions and clearly explained their importance in economic data analysis.

Question 2: Explain the multicollinearity problem, including its causes, detection methods (such as the Variance Inflation Factor), and remedial measures (such as ridge regression, principal component regression).

Grading Criteria:

• 0-2 points: Did not explain multicollinearity or did not mention causes, detection, and remedial measures.

• 3-5 points: Explained multicollinearity but the description of causes, detection, or remedial measures was incomplete.

• 6-10 points: Comprehensively explained the causes of multicollinearity, detection methods, and remedial measures, with clear and accurate descriptions.

Question 3: Discuss the issue of heteroscedasticity, including its causes, detection methods (such as the Breusch-Pagan test), and remedial measures (such as weighted least squares, heteroscedasticity-consistent standard errors).

Grading Criteria:

• 0-2 points: Did not discuss heteroscedasticity or did not mention causes, detection, and remedial measures.

• 3-5 points: Discussed heteroscedasticity but the description of causes, detection, or remedial measures was incomplete.

• 6-10 points: Comprehensively discussed the causes of heteroscedasticity, detection methods, and remedial measures, with clear and accurate descriptions.

Question 4: Describe the serial correlation issue, including its causes, detection methods (such as the Durbin-Watson test), and remedial measures (such as Newey-West standard errors, autoregressive errors).

Grading Criteria:

• 0-2 points: Did not describe the serial correlation issue or did not mention causes, detection, and remedial measures.

• 3-5 points: Described the serial correlation issue but the description of causes, detection, or remedial measures was incomplete.

• 6-10 points: Comprehensively described the causes of the serial correlation issue, detection methods, and remedial measures, with clear and accurate descriptions.

Question 5: Reflect on practice, including the development of self-regulation skills, reflective practice in the model-building process, setting learning objectives, and the adaptability of learning strategies according to the characteristics of the data and specific violations encountered.

Grading Criteria:

• 0-2 points: Did not engage in reflective practice or did not address self-regulation, setting of learning objectives, and adaptability of strategies.

• 3-5 points: Engaged in basic reflective practice but the description of self-regulation, setting of learning objectives, and adaptability of strategies was incomplete.

• 6-10 points: Deeply reflected on the practice process, including self-regulation, reflection on model building, clear setting of learning objectives, and detailed description of the adaptability of strategies.

2. Vertical test(Problem-Solving Test) and grading criteria:

Unit 3

Exam Name: "Dummy Variable Model Case Problem Solving Test"

Total Score of the Exam: 50 points

Exam Content and Grading Criteria:

Case 1: Consumer Purchase Behavior Analysis (Total 25 points)

Background Information:

A retail company wants to optimize its marketing strategy by analyzing consumer purchasing behavior. The company has collected the following data:

- Consumer age (years): [20, 25, 30, 35, 40]

- Gender (Male=1, Female=0): [1, 0, 1, 1, 0]

- Annual income (ten thousand yuan): [3, 5, 7, 9, 11]

- Purchase category (Electronics=1, Clothing=0): [1, 0, 1, 0, 1]

- Purchase frequency (times/month): [1, 2, 3, 2, 4]

Questions:

1) **Dummy Variable Definition and Application** (10 points)

- Define dummy variables for gender and purchase category and apply them in a regression model.

2) **Comparison of Different Encoding Methods** (5 points)

- Compare the advantages and disadvantages of different dummy variable encoding methods.

3) **Model Establishment and Interpretation** (10 points)

- Establish a regression model including dummy variables and interpret the model results.

Case 2: Evaluation of Educational Project Effectiveness (Total 25 points)

Background Information:

An educational institution wants to evaluate the impact of different teaching methods on student learning outcomes. The following data has been collected:

- Student ID: [1, 2, 3, ..., 10]

- Teaching method (Traditional=0, Innovative=1): [0, 1, 0, 1, ...]

- Student weekly study time (hours): [4, 5, 6, ..., 10]

- Semester grade (out of 100): [65, 70, 75, ..., 95]

Questions:

1) **Learning Progress Monitoring** (5 points)

- Describe how to monitor student learning progress using a dummy variable model.

2) **Dummy Variable Model Construction** (10 points)

- Construct a regression model including a dummy variable for teaching method to evaluate the impact of teaching methods on student grades.

3) **Error Identification and Correction** (5 points)

- Identify potential errors in the model and propose corrective measures.

4) **Application Reflection** (5 points)

- Reflect on the applicability and limitations of the dummy variable model in educational evaluation.

Grading Criteria:

Case 1: Consumer Purchase Behavior Analysis (Total 25 points)

1) Dummy Variable Definition and Application (10 points)

0-2 points: Dummy variables are not defined or applied incorrectly, showing a lack of basic understanding.

3-6 points: Dummy variables are defined but not entirely correct in application or unclear in explanation.

7-10 points: Dummy variables are accurately defined and appropriately applied, with clear and reasonable explanations.

2) Comparison of Different Encoding Methods (5 points)

0-1 point: No comparison is made or the comparison is irrelevant.

2-3 points: Different encoding methods are compared but lack depth or accuracy.

4-5 points: A comprehensive comparison of different encoding methods is provided, demonstrating a thorough understanding and clear explanation.

3) Model Establishment and Interpretation (10 points)

0-2 points: The model is incorrectly established or not established at all, with explanations missing or irrelevant.

3-6 points: The model is partially correct but the explanation is insufficient or erroneous.

7-10 points: The model is correctly established, with accurate and insightful explanations.

Case 2: Evaluation of Educational Project Effectiveness (Total 25 points)

1) Learning Progress Monitoring (5 points)

0-1 point: No learning progress monitoring method is shown or the method is not applicable.

2-3 points: Basic monitoring methods are shown but lack innovation or practicality.

4-5 points: Innovative monitoring methods are shown with high practicality.

2) Dummy Variable Model Construction (10 points)

0-2 points: The model is incorrectly constructed or not constructed at all, with variable explanations missing.

3-6 points: The model is partially correct but incomplete in construction or insufficient in explanation.

7-10 points: The model is accurately constructed, with clear and in-depth variable explanations.

3) Error Identification and Correction (5 points)

0-1 point: Errors are not identified or the correction methods are not applicable.

2-3 points: Some errors are identified but the corrective measures are insufficient or incorrect.

4-5 points: Errors are accurately identified and reasonable and effective corrective measures are proposed.

4) Application Reflection (5 points)

0-1 point: No reflection is made or the reflection is irrelevant.

2-3 points: Basic reflection is made but lacks depth or accuracy.

4-5 points: In-depth reflection on the applicability and limitations of the model is provided, demonstrating critical thinking.

APPENDIX E

Three teachers evaluated the test paper design for 5 units, and the assessment data shows a mean score greater than 0.8, indicating that the test paper performed well in clarity, relevance, and difficulty. Three teachers, one professor and two lecturers, have taught or are currently teaching the Econometrics course, and they are the same sample group of teachers who were interviewed in the phase 1.

clarity	Teacher A	Teacher B	Teacher C	mean
unit1	1	0.9	0.8	.90
unit2	1	0.8	0.8	.87
unit3	0.8	1	1	.93
unit4	0.9	0.9	0.8	.87
unit5	0.8	1	1	.93
relevance	Teacher A	Teacher B	Teacher C	
unit1	0.9	1	1	.97
unit2	1	0.9	0.8	.90
unit3	1	1	0.9	.97
unit4	0.9	0.8	1	.90
unit5	1	1	1	.00
appropriate difficulty	Teacher A	Teacher B	Teacher C	
unit1	0.9	0.9	1	.93
unit2	1	1	0.9	.97
unit3	1	0.8	0.9	.90
unit4	0.8	0.8	0.8	.80
unit5	1	0.8	0.9	.90

APPENDIX F

The student self-assessment form also covers 5 units. Here, only the self-assessment form for Unit 3, the Dummy Variable Model, is displayed.

Unit 3 Dummy Variable Model(6 classes)

Self-Assessment Form 1: Knowledge Learning

Name:____________________

Date: ____________________

Understanding of Dummy Variables

I can define dummy variables and explain their function in regression models. (Yes/No)

I understand the different types of dummy variable encoding methods. (Yes/No)

I can identify when to use dummy variables in a regression model. (Yes/No)

Application and Interpretation

I can apply dummy variables in regression models to account for categorical data. (Yes/No)

I can interpret the results of regression models that include dummy variables. (Yes/No)

I understand how to include interaction terms with dummy variables in a regression model. (Yes/No)

Self-Assessment Form 2: Cognitive Strategies

Name:____________________

Date: ____________________

Situational Simulation

I have participated in simulations that demonstrate the use of dummy variables in different economic situations. (Yes/No)

I can apply the concepts learned from simulations to new scenarios. (Yes/No)

Comparative Learning

I have compared dummy variable models with ordinary regression models. (Yes/No)

Practical Operation

I have performed practical operations with dummy variables using data sets. (Yes/No)

Self-Assessment Form 3: Metacognitive Strategies

Name:______________________

Date: ______________________

Learning Monitoring

I actively monitor my progress and understanding of dummy variable concepts. (Yes/No)

Error Identification

I can identify errors in my understanding or application of dummy variables. (Yes/No)

Application Reflection

I reflect on the applicability and limitations of the dummy variable model after its application. (Yes/No)

I can provide feedback on how well the dummy variable model works in practice. (Yes/No)

The number of questions for each unit in the self-assessment form depends on the course content and the proportion of class each unit occupies.

	The number of questions			Class
	Knowledge	Cognitive Strategy	Metacognitive Strategy	
Unit 1	9	6	6	9
Unit 2	9	6	6	9
Unit 3	6	4	4	6
Unit 4	12	8	8	12
Unit 5	9	6	6	9

The scoring of the rationality of the student self-assessment form by five experts.

expert	1	2	3	4	5	mean	SD
unit 1	1	.8	0.8	0.8	1	0.88	0.109545
unit 2	.9	1	1	1	1	0.98	0.044721
unit 3	.8	1	.8	.8	0.8	0.84	0.089443
unit 4	1	.9	1	1	.9	0.96	0.054772
unit 5	1	1	0.9	0.9	1	0.96	0.054772

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