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Improving Junior High School Students' Marine Food Webs Learning Through a SWI-Prolog-Based Interactive Learning System

Jie-Wei Wang[1], Chin-Fei Huang[1,*] and Che-Chern Lin[2]

[1]Graduate Institute of Science Education and Environmental Education,
National Kaohsiung Normal University
[2]Department of Software Engineering and Management, National Kaohsiung Normal University

Abstract

This study investigates the effects of integrating a SWI-Prolog-based interactive learning system in a junior high school students' food webs learning program. An expert system programming language called SWI-Prolog was utilized to build an interactive learning system based on a food webs diagram. One hundred seventh-grade students participated in this study. They were divided into an experimental group and a control group. Both groups were asked to complete a pre- and post-test questionnaire that included a "Food Webs Learning Literacy Test" and questions related to different treatments about learning strategies that were used in this study. The experimental group learned with the SWI-Prolog-based interactive learning system, while the control group learned with photographic cards. The results showed that the SWI-Prolog-based interactive learning system could significantly improve students' food webs knowledge performance and learning behavior.

Key words: Prolog, Auto Reasoning, Food Webs, Expert Systems, Computer Assisted Learning

Introduction

In September 2015, the United Nations announced "Transforming Our World: The 2030 Agenda for Sustainable Development" with 17 Sustainable Development Goals (SDGs). This important declaration attracted the attention of people from all around the world. The content of the agenda implied the necessary attention to environmental protection, life quality improvement, and the importance of ecological sustainability (United Nations, 2015). A stable and safe ecological food webs is one of the most important issues related to ecological sustainability. Food webs, especially marine food webs, are not only a key factor in maintaining

* Corresponding author: Chin-Fei Huang, chinf1027@yahoo.com.tw
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a good cycle of ecological activities, but they also effect on human health. Therefore, the importance of SDGs-14 (life below water) was been focused right now (United Nations). Van Zanten and van Tulder (2021) indicated that economic activities induce negative impacts on SDGs-3 (good health and well-being), SDGs-13 (climate action), SDGs-14, and SDGs-15 (life on land). They mentioned that human being need to face these problems right now. Many studies have shown that the presence of microplastics, chiral pharmaceuticals, namely atenolol, metoprolol, venlafaxine, and chloramphenicol in marine food webs has a long-term, dangerous effect on animals and humans (Carbery, O'Connor, & Thavaman, 2018; Mercogliano et al., 2020; Ruan et al., 2020). In other words, food webs are a basic background concept when considering ecological sustainability development.

Previous studies have illustrated that even children at the earliest stages of their lives have the potential to learn ecology and that it is possible to foster an ecological worldview at this age and suggested that the concepts of food webs or food chains should be taught to younger students to improve their system thinking about ecosystems at an earlier age (Allen, 2017; Inoue, 2020; Matheis & Herzig, 2019). After learning about the role of chemistry in food webs and how humans might be affected by seafood, students can brainstorm about ways to increase food safety whilst considering community needs in regions of the world that may have economic difficulties (Curran & Robertson, 2020). Thus, this study focused on junior high school students' learning about food webs. Besides, since Taiwan is an island state surrounded by sea, marine education and coastal protection issues are important environmental courses in Taiwan. The ambit of food webs was defined for this study in terms of the marine ecosystems in Taiwan's ocean.

Although learning about the concepts of marine food webs is important in the present day, the complicated and dynamic system thinking that is required is very difficult for junior high school students to learn. Past researches indicated that most students consider about the food webs by linear thinking (Allen, 2017; Inoue, 2020; Matheis & Herzig, 2019). For example, many students believe that the death of the most senior consumers is only good for the overall ecosystem, but they won't consider about the problems of ecosystem out of balance. When the most senior consumers extinct, the numerous of secondary consumer might become large and the producers may become extinct. To sum up, many students lack of this kind of mesh system thinking. It needs information technologies to improve students' mesh system thinking.

Furthermore, the main purpose of education for sustainable development is not only to improve students' environmental literacy which involved in environmental knowledge (Larrain, Howe, & Freire, 2018), but also to enhance their environmental attitudes and behavior (Hsu, Lin, Fang, & Liu, 2018). Pe'er, Goldman, and Yavetz (2007) defined environmental knowledge, environmental attitude, and environmental behavior as the three components of environmental literacy.

Today, information technology significantly professionals in the field of early learning. Unlike traditional technical means of education, information, and communication technologies allow not only to fill the child with a large number of ready, strictly chosen, appropriately organized knowledge, but also to develop mental and creative abilities, and what is very important in early childhood—the ability to independently acquire new knowledge (Benedek, Bruckdorfer, & Jauk, 2020). Not only that, but there are many other benefits in using information technology in teaching such as: improves engagement, improves knowledge retention, encourages individual learning, encourages collaboration, students can learn useful life skills through technology (Henderson, 2020). Therefore, it is necessary to introduce information technologies in the system of preschool education and training. In this study, students' food webs learning knowledge, food webs learning attitude, and food webs learning behavior were defined as food webs learning literacy. With the aim of decreasing the difficulties of mesh system thinking of marine food webs learning and improving students' food webs learning literacy (knowledge, attitude, and behavior), this study developed a SWI-Prolog-based interactive learning system using expert systems.

Expert systems are a kind of artificial intelligence technique based on a set of well-structured rules. The main step to build expert systems is to establish knowledge structures for problem domains. To do this, knowledge engineers extract the domain knowledge from human experts, and organize the knowledge in accordance with expert system programming languages. Recently, expert systems have been widely utilized in many fields with successful applications, especially in diagnosis and decision-making systems. The main reason for using expert system programming languages is that these languages have built-in inference engines to perform auto reasoning. Another reason is that they provide well-structured syntax and a library for solving real-world problems. There are two popular programming languages for building expert systems: Prolog and CLIPS. Prolog is a well-known backward reasoning language. It conducts inferencing using a backward-tracking reasoning procedure. CLIPS, on the other hand, conducts its inferencing using a forward reasoning procedure. In this study, we used SWI-Prolog as the expert system programming language to build our system since this system is helpful to guide students learn complex interactions.

Mainly, there are three parts to an expert system: a rule base, an inference engine, and user interfaces. Figure 1 demonstrates a conceptual diagram of a typical expert system. In an expert system, the rule base serves as a knowledge ontology storing a set of rules and facts, where rules represent well-structured domain knowledge and facts indicate existing conditions. In general, rules are not often changed, but facts are changed more frequently. An inference engine is a mechanism to perform auto reasoning by firing a sequence of rules according to a set of facts. Since SWI-Prolog has a built-in inference engine, it is not necessary to implement an inference engine by expert system developers. User interfaces allow users to update facts, manage inference processes, and then display inference results. However, the user interface for SWI-Prolog is a conman-line-based console, which is not suitable for modern computer applications. Therefore, in this study the Java programming language was used to build Graphical User Interfaces (GUIs) for better visualization effects. The business process controls of the proposed system were also implemented in Java. The technical details of how Java builds the GUIs and handles the inference processes are omitted from this study. In general, when a student chooses to let one of the creatures in the food web die, he/she can see the associated changes of other creatures from the

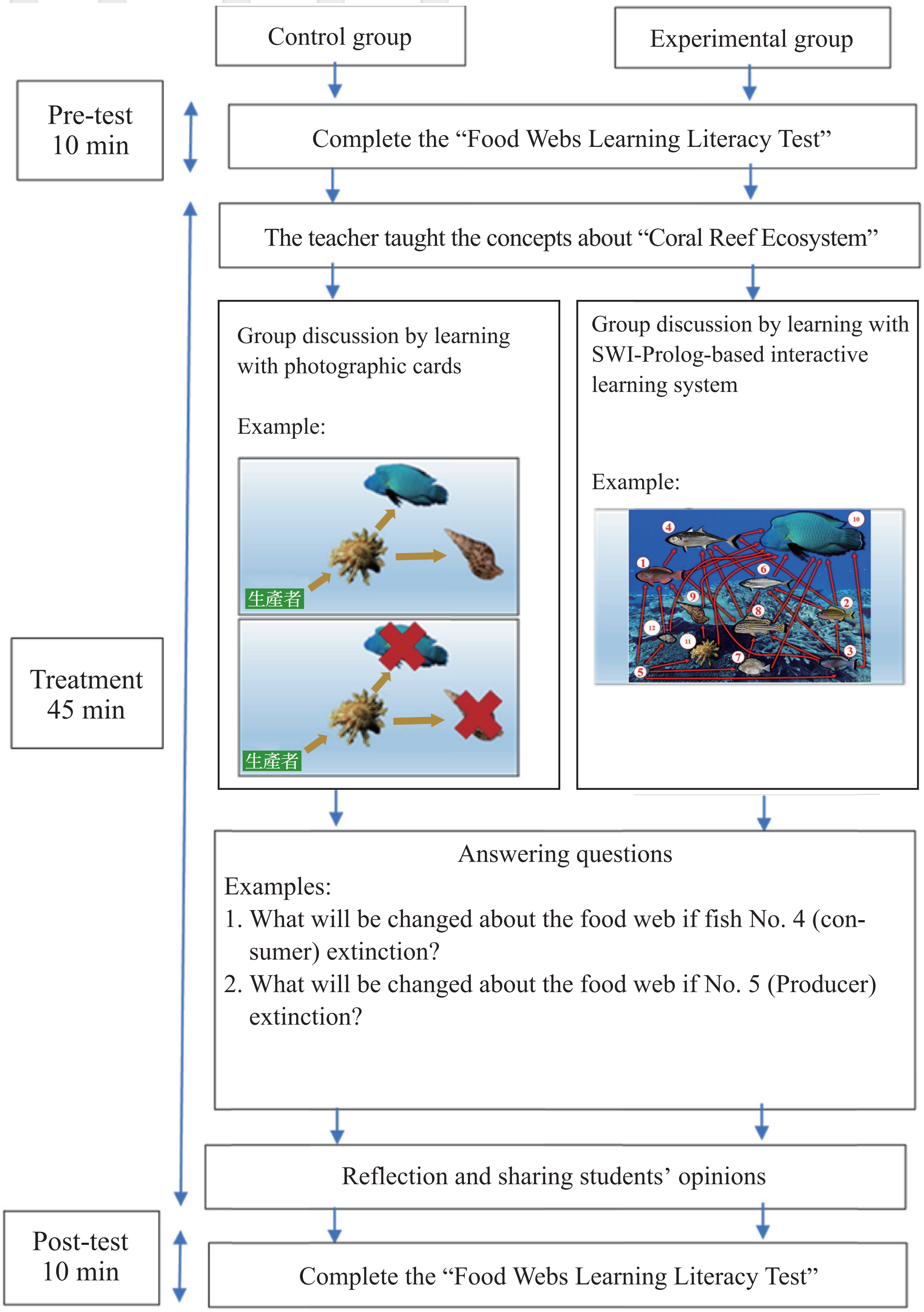

Figure 1. The research flow of the control and experimental groups

computer. This kind of immediately reply could improve students' mesh system thinking, and might can affect their food webs learning literacy. In this study, based on SWI-Prolog, an interactive learning system was proposed to help improve students' mesh system thinking and their learning literacy about the marine food webs system in the oceans around Taiwan. The following research question in this study is: What are the differences in students' marine food webs learning literacy (knowledge, attitude, and behavior) before and after learning with the interactive learning system?

Literature Review

Marine food webs learning literacy

The ocean is one of the core factors to affect the planet ecology and human well-being, however there are few researches explore the educational issue about ocean (Liu, Lin, & Tsai, 2020; Mokos, Realdon, & Čižmek, 2020). Liu et al. mentioned that promote ocean literacy is not only an increasingly important issue in from kindergarten to 12th grade teaching and learning, but also a highly particular important issue in Taiwan. In 2007, the Ministry of Education of Taiwan designated marine education as an important education issue. The core concepts of marine education are familiarity with the ocean, understanding of the ocean and love of the ocean. However, Lee, Ting, Chang, Lee, and Liu (2016) indicated that the real life problems such as flooding, coral bleaching, climate changes, or marine sustainable in marine education are too complex to learn all. To sum up, it is important to find a core concept of marine education for younger students to learn first (Liu et al.).

One of the knowledge domains of understanding the ocean is knowing more about food webs in the marine environment around Taiwan. Wyner and Blatt (2019) explore middle and high school students' concepts about food webs to the food they eat. Their research indicated that people in present-day do not know well where their food from and how their food produced. Furthermore, many students do not aware that human are in the food webs in this whole world. The separation from human to nature food webs might decrease students' concerning about marine ecosystem (Arms, 2008; Wyner & Blatt). In Taiwan, the coral reef ecosystem is one of the most important ecosystems (Carbery et al., 2018). In a coral reef ecosystem, the fishes and living things interact by grazing eclipse, symbiosis, competition, etc. (Lee et al., 2016; Wang, 2019).

Besides, Wyner and Blatt (2019) also indicated that the complex concepts of food webs, such as the emerges transfer between trophic levels of food webs, and the mesh networking of food webs from food chain, will confuse middle and high school students' knowledge learning. Each living marine creature is related to others and affects the balance of the marine food webs. Since the food webs concepts are both important and complex, this concept of marine food webs was adopted to teach and carry out the research. To sum up, in the marine food webs conceptual learning, the logical concepts and the complex interactions of autotrophs, consumers, and decomposers can make students feel that it is difficult to learn.

Furthermore, environmental literacy is the top-level construct established by the research. Citizens with environmental literacy can understand human needs to interact with the environment, and can understand that human cannot survive independently of other organisms (Yang, 1997). Moreover, human with environmental literacy is willing to use the environment reasonably to improve the quality of life. The core concept of environmental education emphasizes the cultivation of environmental literacy, and the environmental literacy involved in environmental knowledge, attitude, and behavior (Pe'er et al., 2007).

Computer-based learning and SWI-Prolog-based interactive learning system

Azevedo and Hadwin (2005) also stated that a computer-based scaffolds design could help students structure their learning scaffolding from complex concepts. Also, Winters, Greene, and Costich (2008) mentioned that computer-based learning environments could foster students' learning of complex concepts. The ability of the computer to reproduce text, graphics, sound, speech, and video simultaneously, and the ability to remember and process data at high speed allows professionals to create new activities for children that are radically different from all existing games and toys. Besides, information technology allows you to increase the amount of material you offer to view and provides an individual-oriented approach. Practice has shown that this significantly increases the interest of children in classes, increases their cognitive abilities (Benedek et al., 2020). To date, a number of studies have supported the argument that students could improve their problem-solving abilities and meta-cognitive abilities through computer-based learning (O. Chen, Woolcott, & Sweller, 2017; Kim, Belland, & Walker, 2018; Maryeni, Siregar, Roza, & Jalinus, 2019). Referring to previous research, this study adopted computer-based learning to help students structure their concepts of marine food webs. On the other hand, Liaw (2008) mentioned that the self-efficacy is a key factor to affect learners' satisfaction with e-learning system. It means that e-learning should design as an interactive system which is related to learner self-operation.

Oliver (1996) defined that the interactive system is a kind of computer skills which could help people process complex mental model framework. In other words, people build their mental modes by interacting a lot of divergence single system, and a small leak will sink a great ship. But if one can extract each single component from a complex system and designed a logical interactive system, the complex mental model framework could be contextualization. In this study, the way of computer-based learning in this study is a kind of self-operation interactive system called the SWI-Prolog-based interactive learning system. Prolog is a popular programming language to build expert systems. It has been widely utilized in many fields, such as diagnostic systems (Babu, Archana, Vineeth, & Veena, 2011; Pratama et al., 2018; Roventa & Rosu, 2009), and software design (Stoianov & Şora, 2010). This kind of system could promote students' interactive learning with computer systems, contextualized the complex mesh networking mental model frameworks and improve the motivation of active learning (Oliver; Pratama et al.).

Furthermore, computer-assisted interactive learning systems are widely used in many fields with successful applications. For example, in engineering, Karady and Holbert (2004) first used Power-Point slides and industry-furnished videos to explain theories related to power engineering, and then applied computers to derive equations and practical applications. Georgilakis, Orfanos, and Hatziargyriou (2014) have implemented an interactive learning tool to teach electrical students to evaluate transmission pricing for small size power systems in a power system economics course. Xu, Lai, Tse, and Ichiyanagi (2011) utilized MATLAB/Simulink, a computer programming language which is powerful in mathematical operations and visualizations, to implement a simulator for electrical circuit education where a multi-session computer-based interactive learning environment was implemented. Zuo (2010) has implemented an interactive learning system to train engineers using web-based multi-media resources. Computer-assisted interactive learning systems could also be employed in mathematics education. For example, Faradisa, Assidiqi, and Zikky (2016) have applied a computer-assisted interactive learning system to help grades six to eight students to learn some basic concepts regarding probability and statistics. Erbas, Ince, and Kaya (2015) used interactive whiteboards and computer-based graphing to teach high students to learning mathematics.

Previous studies related to computer-assisted interactive learning needed to implement learning environments using computer programming languages. It might be a heavy load in writing computer code. In our interactive learning system, we utilized SWI-Prolog to conduct interactive activities, and stored the knowledge structure in a rule base. The rules in the rule base are simple and straightforward. Besides, the interactions between users and the system are automatically conducted by the auto-inference process of SWI-Prolog. Therefore, our system is simple to design and easy to maintain.

With the continuous development of advanced teaching methods, the research and application of learning forms in which students are at the center of the learning process, self-learning knowledge, and raising attitudes studying, applying learning results to life is very necessary. This study not only aimed to improve students' concepts learning, but also to better understand students' growth of food webs learning literacy after teaching and learning. Besides, the research also provides a reliable source of documents for teachers and learners, effective in teaching knowledge about food webs.

Past research has defined environmental literacy as students' environmental knowledge, attitude, and behavior (Hsu et al., 2018; Pe'er et al., 2007). This study referred to this research and took the same definition of food webs learning literacy as food webs learning knowledge, attitude, and behavior. The literacy test and data explanation were developed based on this definition.

Moreover, the SWI-Prolog-based interactive learning system is a very new research field, and there are fewer applications of this field in science education. This also highlights the particularity of this research.

Methods

Participants

There were 100 seventh grade students from Taiwan who participated in this study. They were divided into a control group (n = 50, male = 27, female = 23, mean age = 13.7 years old) and an experimental group (n = 50, male = 24, female = 26, mean age = 13.7 years old). Both groups were taught by the same biology teacher (male, 38 years old, serve as junior high school biology teaching for eight years), and all of them need to complete the Food Webs Learning Literacy Test as pre-test of before learning. The control group received the lecture teaching and learning strategies with photographic cards, while the experimental group received the lecture teaching and learning strategies with the SWI-Prolog-based interactive learning system (Figure 1). The photographic cards are the same contents as experimental group. The different is that the routes of food webs can be operated by using computers by students, while each route of food webs just can be shown in one photographic card. The control group students learn each route of food webs and clarify the relationship of each food chain route by reading the photographic card. At last, all of the participants need to complete the Food Webs Learning Literacy Test again as post-test of after learning.

Instructional design: Lack of educational instructional design

System design-SWI-Prolog's syntax

The characteristic of SWI-Prolog-based interactive learning system is using the immediate response characteristics of computers to teach students the complex knowledge of the food webs. For example, if certain species disappear, how will the marine food web be affected? Students can improve the complex system thinking through SWI-Prolog-based interactive learning system (Blackburn, Bos, & Striegnitz, n.d.).

Through timely and interactive computer screens, students' interest in learning will be enhanced. This learning system provides a simple teaching mode and a more complex test mode to meet the learning needs of students. Through the actual images of the marine food web in the coastal waters of Taiwan, students can understand how the marine food chain will be affected if certain species disappear because of human fishing indiscriminately. In this way, students will be promoted. Environmental and ecological awareness. In our limited knowledge, there are no research discuss about the connection between SWI-Prolog-based interactive learning system and students' environmental attitude and behavior.

There are four fundamental items in SWI-Prolog: atoms, numbers, variables, and complex terms, briefly explained as follows (Blackburn et al., n.d.):

(1) An atom is basically a string representing a certain item in an expert system. It is important to note that the first letter of an atom cannot begin with an upper-case letter.
(2) A number represents either a floating-point number or integer. In most cases, integers are used more frequently in SWI-Prolog's mathematical manipulations since they are countable.
(3) A variable is also a string beginning with an upper-case letter, and could store any possible atom or number when performing reasoning.
(4) A complex item is a multi-item structure consisting of atoms and numbers.

Design of the rule base and GUIs

Figure 2 shows the food webs diagram consisting of 12 fishes numbered from Fish 1 (f1) to Fish 12 (f12), respectively. These 12 fishes were collected by a real word food webs system in Taiwan's nearby ocean which was provided by the practical survey research data from Academia Sinica (https://www.sinica.edu.tw/ch/articles/22).

The figures of these fishes were constructed by Academia Sinica Research Center for Biodiversity (http://shell.sinica.edu.tw) and Kenting National Park's main website (https://www.ktnp.gov.tw). The representativeness of these 12 fishes was examined by three experts of ocean biology. The names of these fishes are indicated in Table 1.

Figure 3 shows the main GUI of the proposed system. There are five situations in the proposed system, as explained in Table 2. In the rule base,

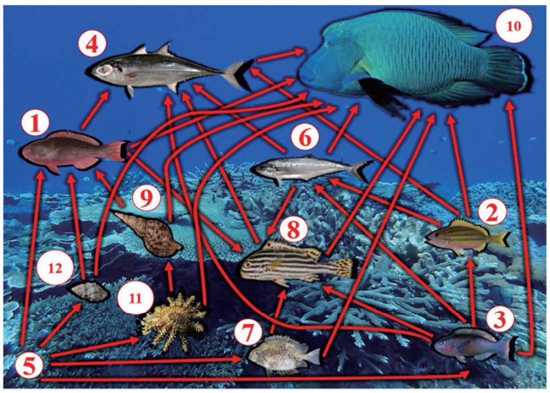

Figure 2. The food webs diagram

Source: "The Fish Database of Taiwan," by K.-T. Shao, 2015 (https://fishdb.sinica.edu.tw).

Table 1. The 12 fishes in Figure 2

Fish ID	Name
Fish 1	*Scarus rubroviolaceus*
Fish 2	*Lutjanus bengalensis*
Fish 3	*Scarus psittacus*
Fish 4	*Megalaspis cordyla*
Fish 5	Produce
Fish 6	*Scomberoides tol*
Fish 7	*Siganus guttatus*
Fish 8	*Plectorhinchus lineatus*
Fish 9	*Charonia tritonis*
Fish 10	*Cheilinus undulatus*
Fish 11	*Acanthaster planci*
Fish 12	*Drupella cornus*

we use five facts/rules to describe the five situations with a one-to-one correspondence. They are:

(1) exist_ext(fish_id): Indicating a fact of whether or not this particular fish exists externally. This fact is associated with the situation of "extinct externally" in Table 2. If this particular fish is extinct externally due to human behaviors, this fact is false; otherwise, it is true.

(2) full_exist(fish_id): Indicating a rule that this particular fish is not affected by the environment. This rule is associated with the situation of "not affected" in Table 2.

(3) half_exist(fish_id): Indicating a rule that this particular fish partially exists. This means that some of the food for this particular fish has disappeared and its enemies still exist. This rule is associated with the situation of "partially extinct" in Table 2.

(4) non_exist(fish_id): Indicating a rule that this particular fish is totally extinct. This means that all foods for this particular fish have disappeared but its enemies still exist. This rule is associated with the situation of "totally extinct" in Table 2.

(5) over_exist(fish_id): Indicating a rule that this particular fish is better able to reproduce (i.e., over breeding). This means that all foods for this particular fish exist and all of its enemies have disappeared. Therefore, the population of this particular fish continues to increase. This rule is associated with the situation of "better to reproduce" in Table 2.

At the beginning of conducting the learning activities, we assumed that all the 12 fishes existed externally. If some fish become extinct externally due to human behaviors, its associated fact should be modified. When conducting learning activities,

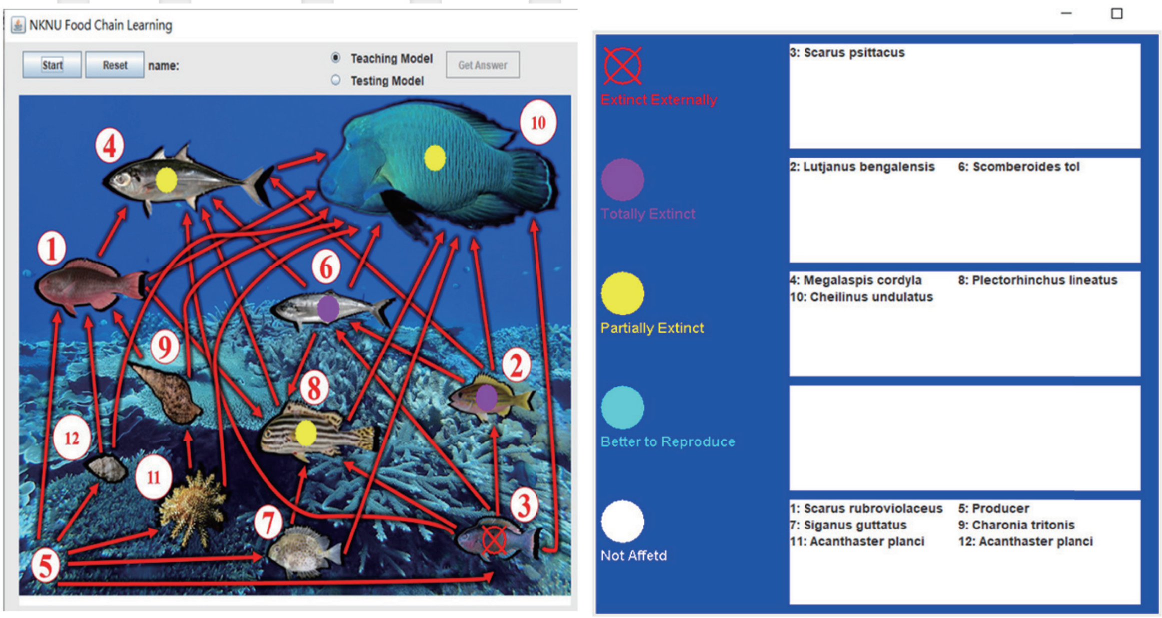

Figure 3. The main Graphical User Interface (GUI) of the proposed system

Source: "The Fish Database of Taiwan," by K.-T. Shao, 2015 (https://fishdb.sinica.edu.tw).

Table 2. The situations in the proposed system

Situation	Explanation
Extinct externally	This fish is extinct externally due to human behaviors.
Totally extinct	All foods for this fish have disappeared but its enemies still exist.
Partially extinct	Some of the foods for this fish have disappeared and its enemies still exist.
Better to reproduce	All foods for this fish exist and all enemies of this fish have disappeared.
Not affected	The fish is not affected by the environment.

a fish can become extinct externally by moving the cursor to the center of the fish and then clicking it.

The teaching and learning model provide the functionality of how fishes' situations change if a particular fish becomes extinct externally due to human behaviors. The testing model allows students to simultaneously make multiple fishes extinct externally, and then they click "get answer" to obtain the results. Also, the testing model can test students' understanding of the outcomes of the food webs diagram when some fishes become extinct due to external causes.

Teaching design of SWI-Prolog-based interactive learning

The learning strategies (models) for this interactive learning system are mainly divided into two stages. The first stage is called "teaching model," and the second one is called "testing model." The two stages are explained as follows.

Teaching model

In this model, we focus on how to teach students to learn the knowledge about marine food web. In this stage, the learning issues are stated as follows:

(1) Learning the fishes and the food marine food web in the nearby sea of Taiwan. To do this, when students move their cursor to the center of a particular fish, the learning system will automatically show the name of this particular fish. The picture of the marine food web is also shown on the main screen of this learning system.
(2) What are the outcomes of the marine food web if some fishes are extinct by human beings? To do this, we designed a rule base storing the rules regarding the inter-reactions among different fishes. If a student clicks a particular fish, this particular fish will be extinct. The outcome of the disappearance of this particular fish will be instantly and automatically shown on the screen.

Testing model

The purpose of the testing model is to provide more complicated cases on how the marine food web will be affected if multiple fishes disappear. The steps of this stage are described as follows:
(1) Step 1: Teachers click multiple fishes to indicate the disappearances of these clicked fishes.
(2) Step 2: Teachers then ask students to think how the marine food web will be affected if these clicked fishes are extinct by human beings.
(3) Step 3: Teachers click the button of “get answer.” The outcomes of the marine food web affected by these extinct fishes will be automatically and instantly shown on the screen.

Food Webs Learning Literacy Test

The “Food Webs Learning Literacy Test” (Appendix) was developed for this study with reference to M.-S. Chen (2009) and the Programme for International Student Assessment (Bybee, 2008). There are three domains and 35 items. The knowledge domain contains 15 items, the attitude domain contains 10, and the behavior domain contains 10. The knowledge domain is designed as single choice questions. The participants get one point when the answer is correct and zero points when they respond with the wrong answer. The attitude domain and behavior domain were designed using a 5-point Likert scale (5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; 1 = strongly disagree). This test achieved content validity according to three experts’ reviews and passed pilot study through 177 participants (mean age = 13.8 years old). The reliability of the knowledge domain from pilot study reached KR_{20} = .641. The result of KR_{20} analysis from knowledge domain is not very high since the item discrimination index of item eight (item discrimination = 0.126) and item nine (item discrimination = 0.166) is lower. However, this study retained these two items. The reason is that these two items are important concepts in this study and the previous study supported that the reliability of test can be accepted when KR_{20} analysis data upper than 0.6 (Tu, 2020). The reliability of the attitude domain reached a Cronbach’s α of .896, and the reliability of the behavior domain reached a Cronbach’s α of .893. The reliability of the whole “Food Webs Learning Literacy Test” reached a Cronbach’s α of .884. These data indicate that the “Food Webs Learning Literacy Test” has stable and good validity and reliability.

Data analysis

The pre- and post-test data from the control and experimental groups were analyzed using SPSS version 22.0. Analysis of Covariance (ANCOVA) statistical analysis and paired sample t test methods were used to analyze the collected data.

Results and Discussion

In this study, food webs learning literacy was defined as the combination of three domains, specifically food webs learning knowledge, attitude, and behavior, referring to Pe'er et al. (2007). To clearly understand the students' food webs learning literacy performance, the results of each domain are discussed as follows.

The analysis of food webs learning knowledge

In this study, 100 students were divided into a control group and an experimental group. Both were asked to complete the "Food Webs Learning Literacy Test" first as a pre-test. Then, they needed to join a session about food webs concepts. Lastly, all of them were asked to complete the same "Food Webs Learning Literacy Test" as a post-test. The difference in treatment is that the control group received the lecture teaching and learning strategy with photographic cards, while the experimental group received the lecture teaching and learning strategy with the SWI-Prolog-based interactive learning system.

The results from the paired sample *t* test analysis showed that both the control and experimental groups had significantly higher performances of environmental literacy after food webs learning than before (Table 3). This indicates that both groups of students improved their food webs learning literacy through food webs session learning.

Since these two groups of students might have had different food webs learning literacy in the beginning, the data of the food webs learning literacy pre-test were used as the covariance in the ANCOVA analysis. The results in Table 4 reflect that there are no significant differences in the food webs learning literacy of the students learning with the SWI-Prolog-based interactive learning system and the photographic card learning strategies.

Table 3. The paired sample *t* test analysis of food webs learning literacy

Group	*n*	Mean	*SD*	*t*	*p*
Control group	50			-4.29	< .001
Pre-test		62.46	9.54		
Post-test		68.06	7.98		
Experimental group	50			-4.52	< .001
Pre-test		64.54	11.92		
Post-test		71.84	7.90		

Note: *SD*: Standard Deviation.

Table 4. The analysis of covariance analysis of food webs learning literacy

Source	*df*	*MS*	*SS*	*F*	*p*	η^2
Corrected model	3	494.46	1,483.37	9.39	< .001	.227
Intercept	1	6,500.67	6,500.67	123.50	< .001	.563
Total scores of pre-test	1	1,125.09	1,125.09	21.37	< .001	.182
Group	1	77.12	77.12	1.47	.229	.015
Total	100		495,837.00			

Note: *df*: Degrees of Freedom; *MS*: Mean Square; *SS*: Sum of Squares.

Past studies have indicated that literacy involves knowledge, attitude, and behavior (Hsu et al., 2018; Pe'er et al., 2007). To clearly understand the changes in students' food webs learning knowledge, attitude, and behavior after and before learning with the different strategies, these three domains were analyzed individually.

In the food webs learning knowledge domain, the results from the paired sample *t* test analysis showed that both the control and experimental groups had significantly higher performances after food webs learning (Table 5). This indicates that both groups of students improved their food webs learning knowledge through the food webs session learning. Wyner and Blatt (2019) indicated that the concepts of food webs are very complex and confusing students' conceptual structures. In this study, the result may can reflect that this kind of system thinking could be improved by SWI-Prolog-based interactive learning system. This finding was supported by Wen et al. (2020) which indicated that inquiry computer simulations can improve students' understanding of science concepts.

Since these two groups of students might have had different background food webs learning knowledge, the data of the food webs learning knowledge pre-test were used as the covariance in the ANCOVA analysis. The results in Table 6 reflect that the students who learned using the SWI-Prolog-based interactive learning system had significantly better performances of food webs learning knowledge than those who learned using the photographic cards learning strategy.

The findings from Tables 5 and 6 could be supported by the past studies (Allen, 2017; Huang, Hew, & Lo, 2019; Hwang, Yin, & Chu, 2019). Allen mentioned that practitioners could improve students' ecological education to a far greater level. This study provides a SWI-prolog-based interactive learning system to let students be practitioners,

Table 5. The paired sample *t* test analysis of food webs learning knowledge

Group	*n*	Mean	*SD*	*t*	*p*
Control group	50			-2.13	.038
Pre-test		3.50	1.18		
Post-test		3.88	1.06		
Experimental group	50			-4.13	< .001
Pre-test		3.44	1.37		
Post-test		4.30	0.89		

Note: *SD*: Standard Deviation.

Table 6. The analysis of covariance analysis of food webs learning knowledge

Source	*df*	*MS*	*SS*	*F*	*p*	η^2
Corrected model	2	6.10	12.20	6.88	.002	.124
Intercept	1	130.36	130.36	147.05	< .001	.603
Total scores of pre-test	1	7.79	7.79	8.79	.004	.083
Group	1	4.69	4.69	5.29	.024	.052
Total	100		98.19			

Note: *df*: Degrees of Freedom; *MS*: Mean Square; *SS*: Sum of Squares.

and the learning outcomes show that their performances were enhanced. Besides, both Huang et al. and Hwang et al. mentioned that flipped learning using interactive technology could promote students' active learning and higher order thinking. In this study, the results show that the students who learned by interacting with technology could improve their environmental background knowledge and complex food webs knowledge.

The results of students' food webs learning attitude were then analyzed by paired sample *t* test. The findings show that both the control and experimental groups had significantly higher performances in the food webs learning attitude domain (Table 7). This indicated that both groups of students improved their food webs learning attitude through session learning.

Also, since these two groups of students might have had different food webs learning attitudes in the beginning, the data of the food webs learning attitude pre-test were used as the covariance in the ANCOVA analysis. The results in Table 8 show that there is no significant difference in the food webs learning attitudes of the students who learned with the SWI-Prolog-based interactive learning system and the photographic cards learning strategies after food webs learning.

To briefly summarize, both the control and experimental group students in this study showed better performances of food webs learning attitude after learning than before, but there was no significant difference as a result of the different learning strategies.

Gustria and Fauzi (2019) indicated that students' food webs learning attitudes related to abstract concepts are not easy to improve unless the concepts are related to their school curriculum. In this study, the findings show that both the control and experimental groups performed better after teaching and learning the food webs concepts, but

Table 7. The paired sample *t* test analysis of food webs learning attitude

Group	*N*	*Mean*	*SD*	*t*	*p*
Control group	50			-4.61	< .001
Pre-test		22.89	4.52		
Post-test		25.56	3.76		
Experimental group	50			-3.28	.002
Pre-test		24.30	5.16		
Post-test		26.50	3.97		

Note: *SD*: Standard Deviation.

Table 8. The analysis of covariance analysis of food webs learning attitude

Source	*df*	*MS*	*SS*	*F*	*p*	η^2
Corrected model	2	184.58	369.16	16.05	< .001	.249
Intercept	1	1,141.15	1,141.15	99.21	< .001	.506
Total scores of pre-test	1	347.07	347.07	30.17	< .001	.237
Group	1	3.14	3.14	2.73	.603	.003
Total	100		69,241.00			

Note: *df*: Degrees of Freedom; *MS*: Mean Square; *SS*: Sum of Squares.

there was no significant difference between learning by using photographic cards and by the SWI-Prolog-based interactive learning system. The possible reasons why all students' food webs learning attitude improved might be that the concepts of food webs in a coral reef ecosystem are related to the biology courses of junior high school. However, a short period of time spent using different teaching and learning strategies might not be an important factor influencing students' food webs learning attitudes.

Furthermore, this study used paired sample *t* test analysis to explore students' food webs learning behavior. The results show that both the control and experimental groups got significantly higher performances in the food webs learning behavior domain (Table 9). This illustrates that both groups of students improved their food webs learning behavior intentions through the food webs of coral reef ecosystem session learning.

As stated above, the data of the food webs learning behavior pre-test were used as the covariance in the ANCOVA analysis. The results in Table 10 indicate that the students who learned using the SWI-Prolog-based interactive learning system had significantly better performances of food webs learning behavior than those who learned using the photographic cards learning strategy.

Many previous studies indicated that the environmental behavior would be influenced by environmental attitude (Lange & Dewitte, 2019; Liao, Shen, & Shi, 2020; Otto, Evans, Moon, & Kaiser, 2019). In this study, the findings show that there was no significant difference in the different groups of students' food webs learning attitude, but there was a significant difference in the food webs learning behavior of these two groups. One possible explanation could reference Vesely, Klöckner, and Brick (2019) mentioned that pro-environmental behavior might be a key ability of social

Table 9. The paired sample *t* test analysis of food webs learning behavior

Group	*N*	Mean	*SD*	*t*	*p*
Control group	50			-2.91	.005
Pre-test		17.98	2.93		
Post-test		19.31	2.59		
Experimental group	50			-4.35	< .001
Pre-test		18.40	3.58		
Post-test		20.52	2.39		

Note: *SD*: Standard Deviation.

Table 10. The analysis of covariance analysis of food webs learning behavior

Source	*df*	*MS*	*SS*	*F*	*p*	η^2
Corrected model	2	56.51	113.03	10.27	< .001	.249
Intercept	1	693.59	693.59	125.99	< .001	.506
Total scores of pre-test	1	76.43	76.43	13.88	< .001	.237
Group	1	29.95	29.95	5.44	.022	.003
Total	100		40,307.75			

Note: *df*: Degrees of Freedom; *MS*: Mean Square; *SS*: Sum of Squares.

interaction. When the students faced social dilemma questions, they tended to choose the answers which fit the common social value. In other words, one of the possible reason is because although the students' food webs learning attitude was not high enough, they will perform higher food webs learning behavior as a result of retraining with the social trends. However, this is just an inference and needs to be confirmed by further research in the future.

Conclusion

The purpose of this study was to explore the effects of integrating a SWI-Prolog-based interactive learning system in food webs learning. Past researches indicated that many students lack of mesh system thinking and consider about the food webs by linear thinking. In this study, we utilized SWI-Prolog to build the proposed food webs learning system and used Java to establish the GUIs for better visualization. The SWI-Prolog is an interactive learning system was proposed to help improve students' mesh system thinking and their learning literacy about the marine food webs system in the oceans around Taiwan. A unique and significant contribution of this study is that, to our knowledge, there was no research apply SWI-Prolog interactive learning system in science education, especially in marine food webs issue. Therefore, this study is the first and may initiate the extended use of this system in science education. In other words, this research is an example of the cross-field integration of information technology and science education, and it is indeed helpful for students' marine food webs learning. There are four main findings in this study as follows:

(1) The results showed that both the control and experimental groups had significantly higher performances of environmental literacy after food webs learning than before. But there are no significant differences in the food webs learning literacy of the students learning with the SWI-Prolog-based interactive learning system and the photographic card learning strategies.

(2) Both experiment and control groups of students improved their food webs learning knowledge through the food webs session learning, and the students who learned using the SWI-Prolog-based interactive learning system had significantly better performances of food webs learning knowledge than those who learned using the photographic cards learning strategy. The results show that the students who learned by interacting with technology could improve their environmental background knowledge and complex food webs knowledge.

(3) Both experiment and control groups of students improved their food webs learning attitude through session learning, but there was no significant difference between these two groups by learning with the different learning strategies.

(4) Both experiment and control groups of students improved their food webs learning behavior through the food webs session learning, and the students who learned using the SWI-Prolog-based interactive learning system had significantly better performances of food webs learning behavior than those who learned using the photographic cards learning strategy.

This researched resource will be a reliable source for reference for teachers and learners. It can be widely applied throughout Taiwan and can be developed and supplemented with other ecological knowledge to become more comprehensive in educating students. In this study, the results implied that the complex concepts of food webs learning issue are suitable to be designed as an e-learning through SWI-Prolog-based interactive learning system, and this kind of e-learning could improve students' learning knowledge and attitude.

The rule base of the proposed system stored the knowledge structure of the food webs diagram. The proposed system also provided two learning models: a teaching and learning model and a testing model according to users' needs. A total of 100 seventh grade students participated in this study. The results indicated that the students who learned about food webs by using the SWI-Prolog-based interactive learning system showed better knowledge achievement and higher food webs learning behavior performance than those who learned using photographic cards. On the other hand, there was no significant difference in the food webs learning attitudes of those students who learned using the SWI-Prolog-based interactive learning system and those who learned using photographic cards. However, both groups showed significantly higher scores of food webs learning attitude after the food webs learning compared with before. The results of this study imply that students' food webs learning attitude can be improved by a session of teaching and learning if that session is highly connected with environmental issues, but it might not depend on the different teaching or learning strategies.

On the other hand, the viewpoint of computer technology, the advantages of using SWI-Prolog to build interactive learning systems are highlighted as follows. First, the design of learning systems is easy, saving a lot of programming work. Second, it is not necessary to implement inference algorithms since SWI-Prolog has its built-in inference engine to perform auto-reasoning, this kind of auto-reasoning could help to build students' conceptual structures and improve their literacy learning. Third, the rules of computer technology are simple, straightforward, and easy to maintain. A possible limitation in this study was that the participants were all in seventh grade and learned the food webs issue for just one hour, which may affect the generalizability of research findings about "students' further behavior."

This research suggests that future research can summarize and analyze the common mistakes or difficulties which students have in learning ecological concepts by using the "student learning path recorded by the analysis system."

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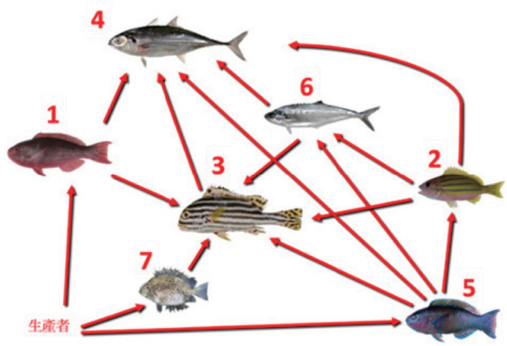
Appendix: The details of the Food Webs Learning Literacy Test

Domain	Items
Food webs learning knowledge	(1) Two organisms live together for mutual assistance can be defined as: (A) Symbiosis (B) Parasitism (C) Competition
	(2) What happens to the coral after the symbiotic algae leaves the coral? (A) No changes (B) More health (C) Die
	(3) If the food chain is contaminated by chemical poisons, which organism will accumulate the most poisons in its body? (A) Producer (B) Primary consumer (C) Senior consumer
	(4) What is the state of the species to form a stable food web? (A) Species simplification (B) Species diversity (C) The stability of the food web is not depending on the state of the species
	(5) If the producer goes extinct, what is the most likely phenomenon of the food web? (A) The food web collapses (B) The food web becomes more stable
	(6) *Charonia tritonis* are the natural enemies of the crown-of-thorns starfish. What might happen if humans catch all the *Charonia tritonis?* (A) Crown-of-thorns starfish exploded and the food web was unbalanced (B) Crown-of-thorns starfish increased in number, and the food web quickly recovered stability
	(7) If the top consumers of a food web become extinct, the food web will (A) have no impact and maintain a balance (B) the number of secondary consumers will increase, and the food web will quickly maintain balance again (C) the number of secondary consumers will increase, and the food web will not balance, may collapse
	(8) Energy received by more advanced consumers: (A) More (B) Less
	(9) The more complex the food web, the ecosystem will be: (A) The more stable (B) The more unstable
	(10) It can be distinguished from picture card (X) that fish No. 5 is the most advanced consumer, so humans can eat fish No. 5 more, because even if No. 5 is extinct, it will not affect the food web? (A) Correct (B) Error
	(11) It can be distinguished from picture card (X) that if fish No. 5 is extinct, which fish in the food web will be directly affected? (All right points are given)



Picture Card X

	(12) The marine environment and fishery resources are related to what kind of fish humans eat? (A) True (B) False
	(13) Humans live on land, so even if humans eat seafood, it will not affect the food web of marine life? (A) True (B) False
	(14) What does coral bleaching mean? (A) Symbiotic algae leave the coral body (B) Coral suffers from bleaching (C) Coral dies (D) Coral becomes healthy
	(15) What is the main reason why symbiotic algae leave the coral body? (A) Symbiotic algae will leave the coral body when they grow up. It is a natural phenomenon. (B) The environment is unfavorable to the symbiotic algae. (C) Healthy corals will secrete toxins to make the symbiotic algae leave.

Food webs learning attitude	(1) I think it is very meaningful to learn about coral reef waters. (2) I think the coral reef area is closely related to human life. (3) If I have the opportunity, I would like to see the coral reef ecosystem. (4) I hope that outdoor teaching can visit places related to coral reefs. (5) I think everyone should have some knowledge about coral reefs. (6) I will pay attention to coral conservation issues. (7) I will pay attention to the issue of ecosystem balance. (8) When I eat seafood, I will focus on whether people's consumption of this kind of seafood will cause adverse effects on the marine environment. (9) I think the stability of the marine life food web is very important to the global environment. (10) I think everyone should protect marine biodiversity.
Food webs learning behavior	(1) When I go to the coral reef to play, I will not bring back natural ecological resources at will. (2) When I go snorkeling in the coral reef waters, I will take care not to step on the corals. (3) I will try my best to pick farmed fish to eat. (4) When I go to the coral reef to play, I will not throw away rubbish at will. (5) When I go to the coral reef to play, I will persuade others not to bring back natural ecological resources at will. (6) When I go snorkeling in the coral reef area, I will persuade others not to step on the coral. (7) I will persuade others to try to pick farmed fish to eat. (8) When I see someone throwing away rubbish at will, I will persuade or report him/her. (9) I will persuade others not to pollute rivers and drains. (10) I will inform relatives and friends of the importance of marine biodiversity.

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運用以 SWI-Prolog 為基礎之互動學習系統增進國中生海洋食物網學習之研究

王傑瑋[1]　黃琴扉[1、*]　林哲正[2]

[1]國立高雄師範大學　科學教育暨環境教育研究所
[2]國立高雄師範大學　軟體工程與管理學系

摘要

本研究主要目的為探討「運用以 SWI-Prolog 為基礎之互動學習系統對於國中生海洋食物網學習之效益」。本研究主要採用 SWI-Prolog 專家系統程式語言，建置海洋食物網互動式學習系統，並藉此探討該互動式學習系統對於國中生海洋食物網學習之成效。本研究之研究對象共有 100 位七年級學生，並分為實驗組與對照組；實驗組與對照組均需於研究進行前完成「食物網學習素養量表」之前測，接著，實驗組採用以 SWI-Prolog 為基礎之互動式學習系統進行海洋食物網相關主題之學習，而控制組則是採用傳統的圖卡式學習；最後，兩組均需於學習後完成「食物網學習素養量表」之後測。研究結果指出，相較於圖卡式學習而言，以 SWI-Prolog 為基礎之互動式學習系統可以提升學生海洋食物網之概念知識與學習態度，且兩者達顯著差異。本研究建議後續研究可深化 SWI-Prolog 專家系統程式語言之運用，進一步建構學生相關科學學習困難之路徑追蹤。

關鍵詞：Prolog、自動推論、食物網、專家系統、電腦輔助學習

*通訊作者：黃琴扉，chinf1027@yahoo.com.tw