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The Effects of Different On-line Searching Activities on High School Students' Cognitive Structures and Informal Reasoning Regarding a Socio-scientific Issue

Ying-Tien Wu · Chin-Chung Tsai

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Abstract Learners' ability in dealing with socio-scientific issues has been highlighted in contemporary science education. This study explored the effects of different on-line searching activities on high school students' cognitive structure outcomes and informal reasoning outcomes. By using a quasi-experimental research approach, thirty-three students were assigned to a "guided searching task group", while thirty-five students were assigned to an "unguided searching task group". The treatments of this study were two different on-line searching activities. All the participants were asked to search relevant information regarding nuclear power usage on the Internet during the period of two classes (100 min). However, the students in the un-guided searching task group were asked to search freely, while those in the guided searching task group were provided with a searching guideline. The participants' cognitive structures outcomes as well as their informal reasoning outcomes regarding nuclear power usage were assessed before and after the conduct of on-line searching tasks. The results of ANCOVA revealed that the students in the guided on-line searching task group significantly outperformed their counterparts in the extent ($p<0.01$) and the richness of their cognitive structures ($p<0.01$). Also, they significantly outperformed their counterparts in the usage of the two information processing strategies, "comparing" ($p<0.05$) and "inferring or explaining" ($p<0.05$). Moreover, it was also found that the students in the guided on-line searching task group only outperformed their counterparts in their supportive argument construction ($p<0.05$). In other words, the guided searching tasks did help the students obtain better cognitive structure outcomes; however, the increments on their cognitive structure outcomes may only help them to propose more

Y.-T. Wu (✉)
Graduate Institute of Network Learning Technology, National Central University, Jhongli City, Taiwan
e-mail: ytwu@cl.ncu.edu.tw

C.-C. Tsai
Graduate Institute of Digital Learning and Education,
National Taiwan University of Science and Technology, Taipei, Taiwan

Present Address:
Y.-T. Wu
No.300, Jhongda Rd, Jhongli City, Taoyuan County 32001, Taiwan

supportive arguments, but their rebuttal construction (an important indicator for their reasoning quality) was not particularly improved.

Keywords Socio-scientific issues · Cognitive structure · Informal reasoning · The flow map method · On-line searching

Introduction

With the tremendous advancements in science and technology, the goals for contemporary science education have been re-defined (Cajas 2001). In particular, in the last two decades, some social dilemmas with conceptual or technological associations with science (often termed "socio-scientific issues"), such as global warming, genetic engineering, and nuclear power usage, have arisen and have been increasingly highlighted by many science educators (e.g., Bell and Lederman 2003; Kolsto 2001; Sadler 2004; Zeidler et al. 2002). Consequently, improving learners' ability in dealing with these dilemmas has been regarded as one of the important goals for modern science education (e.g., AAAS 1989, 1993).

When dealing with a socio-scientific issue, an individual learner often has to make decisions about what to believe or what actions to take, and different reasons or evidence may exist both supporting and not supporting the conclusion he/she makes. In general, informal reasoning involves the generation and evaluation of a position in response to complex issues that lack clear-cut solutions (Sadler 2004). The negotiation and resolution of socio-scientific issues have been generally characterized by the process of informal reasoning, rather than formal reasoning (Sadler 2004). Recently, more and more educators have acknowledged that student informal reasoning ability plays an important role when dealing with socio-scientific issues (e.g., Sadler 2004).

The critical role of rebuttal construction in students' informal reasoning regarding a socio-scientific issue has been advocated (e.g., Wu and Tsai 2007). Researchers in educational psychology have also argued the critical role of rebuttal construction in informal reasoning (e.g., Kuhn 1993). Recently, Sadler and Zeidler (2004) have proposed that, when reasoning on a socio-scientific issue, learners may display flowed reasoning, which includes supportive argument construction, counter-argument construction, and rebuttal construction. Based on the aforementioned perspectives, rebuttal construction could be viewed as one of the important indicators for their informal reasoning ability or reasoning quality (Wu and Tsai 2007). However, the findings derived from previous studies have revealed that, when dealing with socio-scientific issues, students may have difficulty in proposing rebuttals (e.g., Wu and Tsai 2007). It suggests that how to improve learners' reasoning quality when they deal with socio-scientific issues should be one of the important issues for science educators.

To address the aforementioned important issue, the findings derived from previous studies (e.g., Hogan 2002; Kolsto 2001; Sadler 2005; Sadler and Zeidler 2004) may provide some possible directions. Kolsto (2001) has advocated that students' acquired knowledge in science classrooms can serve as tools for their informal reasoning and decision-making on socio-scientific issues. Moreover, previous empirical studies have revealed the significant role of student conceptual understanding in their informal reasoning regarding socio-scientific issues (e.g., Hogan 2002; Sadler 2005; Sadler and Zeidler 2004). It seems that, to improve learners' reasoning quality, educators should try to facilitate their conceptual understanding regarding a socio-scientific issue. Then, their improved conceptual understanding regarding this issue can serve as tools for them to improve their reasoning quality.

To facilitate learners' conceptual understanding regarding a socio-scientific issue, on-line inquiry activities may be helpful. In the last two decades, the Internet-based instruction, integrating the Internet into science teaching and learning, has been largely implemented to improve student learning outcomes in science education (e.g., Hsu et al. 2008; ChanLin 2008). Jonassen (1996, 2000) has argued that the Internet can be utilized as a *cognitive tool* to help learners acquire knowledge, and learn how to reorganize knowledge. It seems that, when an individual learner encounters a socio-scientific issue and has to make his (or her) personal decision on this issue, he (or she) may try to search for relevant information regarding this issue on the Internet. The information he (she) has searched on the Internet may contribute to his (her) reasoning and decision-making on this issue. In other words, the Internet may be used as a tool for improving learners' conceptual understanding regarding a socio-scientific issue, and, sequentially, the quality of their informal reasoning on this issue may be improved. However, only few empirical studies have been conducted to examine the aforementioned perspective. To address the aforementioned issue, as one of the initial attempts, this study tried to explore the effects of different on-line searching activities on students' conceptual understanding and informal reasoning outcomes regarding a socio-scientific issues.

Over the past decades, efficiency in learning has been highlighted by educators and instructional scientists (Clark et al. 2006). It is believed that efficient instruction settings result in learning that is faster and/or better than settings that are inefficient. Consequently, how learning environments can be designed to optimally facilitate students' knowledge has been one of the significant issues for researchers (Segers and Verhoeven 2009). With our understanding of human cognitive architecture, "cognitive load theory" has been proposed to address the aforementioned important issue. In fact, Cognitive load theory (CLT) involves a set of learning principles that are proven to result in efficient instructional environments as a consequence of leveraging human cognitive learning process (Clark et al. 2006). Cognitive load theory assumes a cognitive architecture consisting of a working memory that is limited in capacity when dealing with novel information, and this theory is concerned with techniques for managing working memory load in order to facilitate the change in long-term memory associated with schema construction and automation (Pass et al. 2004). There are three types of cognitive load (i.e., working memory load) (Clark et al. 2006): *intrinsic load*, *germane load*, and *extraneous load*. Intrinsic load is the mental load imposed by the complexity of the content being learnt and is primarily determined by instructional goals. Extraneous load is defined as unnecessary extra load due to poorly designed instruction, while germane load is defined as load that contributes to learning. The three forms of cognitive load are additive in that, taken together, the total load cannot exceed the working memory available if learning is to occur (Paas et al. 2003). According to CLT, to improve efficiency in learning, teachers should try to maximize learners' germane load and minimize their extraneous load in instructional settings. For a long time, debates about the effectiveness of instructional guidance during students' learning have been ongoing. Many researchers have advocated that guided instruction concurs with our current understanding of human cognitive architecture as well as the cognitive load perspective (e.g., Kirschner et al. 2006). Also, the superiority of guided instruction has been empirically examined (e.g., Klahr and Nigam 2004). Undoubtedly, this study is concerned with comparisons of learning efficiency in different instructional settings, and may provide empirical data that reconfirm the findings derived from research regarding the effectiveness of guided instruction.

Current practice in science education encourages the use of multiple ways to assess conceptual learning outcomes. For a long time, the measurement of learners' "cognitive structures" has been regarded as a useful alternative assessment method for assessing learners' conceptual understanding (Shavelson 1974; Tsai 2001; Wu and Tsai 2005a, b). Educators and cognitive scientists have tried to represent acquired knowledge in terms of "cognitive structure" (Pines 1985; West et al. 1985). Through probing learners' cognitive structures, science educators can understand what learners have already acquired (Shavelson et al. 1990). In particular, the effectiveness of different instructional strategies on students' conceptual learning can also be compared by exploring the students' cognitive structures (Ifenthaler et al. 2010). In the relevant studies exploring the relationship between students' conceptual understanding and their informal reasoning regarding a socio-scientific issue, learners' conceptual understanding was mostly assessed by a traditional assessment method, such as multiple-choice questions (e.g., Sadler 2005; Sadler and Zeidler 2004). Alternative assessment method for assessing students' conceptual learning outcomes will be helpful to provide different insights into relevant issues. To provide deeper insights into the effects of different on-line searching activities on students' learning outcomes regarding a socio-scientific issue, the participants' conceptual learning outcomes derived from on-line searching activities were evaluated by comparing their cognitive structure outcomes regarding this issue before and after the implementation of on-line searching activities.

Method

Subjects and the Socio-scientific Issue

The subjects of this study were 68 tenth graders (46 males and 22 females) coming from two classes from a high school in middle Taiwan. For the energy shortage problem, there is often a fierce debate on whether the fourth nuclear power plant should be built in Taiwan. Before this study was conducted, these participants had already learned about nuclear energy usage in their physical and earth science classes. In this study, "nuclear power usage" was used as the socio-scientific issue for the participants to reason.

Research Design and Procedures

By using a quasi-experimental research approach, one class of 33 students was assigned to a "guided on-line searching task group", while the other class of 35 students was assigned to an "unguided on-line searching task group". Before this study was conducted, the participants' cognitive structures as well as their informal reasoning regarding nuclear power usage were assessed.

The research treatments of this study were two different on-line searching tasks. In this study, the participants were asked to search relevant information regarding nuclear power usage on the Internet (100 min). The duration of the treatments of this study (i.e., 100 min) is close to the average time that students in Taiwan may spend on their homework involving an on-line searching task. Zohar and Nemet (2002) have reported the effectiveness of the integration of explicit teaching of reasoning patterns into the instruction of human genetics on genetics knowledge as well as on their argumentation quality. Wu and Tsai (2007) also suggested a reasoning framework, guiding learners to reason from multiple perspectives, which can be used to guide their informal reasoning on a socio-scientific issue. Therefore, two on-line searching tasks with different work sheets were designed and conducted in this study. Both the searching tasks provided the students with work sheets. In these work sheets, the participants were asked to answer the same questions. However, one work sheet asked the participants to search relevant information regarding nuclear power usage freely, while the other provided a search guideline for them. The worksheet used in the un-guided group only contained the sentences that asked the students to search relevant information on the Internet (freely) and summarized what they had searched in a report. To help the students in the guided on-line searching task group find out relevant information regarding nuclear power usage from multiple perspectives and search more efficiently, the searching guideline was used to remind the students to search relevant information regarding nuclear power usage from science-oriented or technology-oriented, economic-oriented, ecology-oriented, social-oriented, and other perspectives. However, neither the guided on-line searching group nor the un-guided on-line searching group was directed to specific web sites. After completing the searching tasks, the participants' cognitive structures as well as their informal reasoning outcomes regarding nuclear power usage were assessed again.

Instruments, Data Collection and Data Analyses

There are two major variables involved in this study: students' cognitive structure outcomes regarding nuclear power usage and informal reasoning outcomes regarding nuclear power usage. A detailed description about the data collection and data analyses of these variables is as follows:

1. *Exploring students' cognitive structure regarding nuclear power usage:*

In this study, the students' cognitive structure outcomes regarding nuclear power usage were assessed before and after the implementation of on-line learning activities. Based upon the review conducted by Tsai and Huang (2002), the "flow map method" may be the most useful method to represent learners' cognitive structures. Therefore, the "flow map method" was used to explore students' cognitive structures about nuclear power usage in this study.

To probe learners' cognitive structures about nuclear power usage, students' narratives were obtained through tape-recorded interviews, and the following non-directive questions were asked by researchers:

(1) Can you tell me what you know about nuclear power or nuclear power usage?
(2) Could you tell me more about the ideas you have mentioned?
(3) Could you tell me the relationships between the ideas you have mentioned?

Then, all the tape-recorded narratives were transcribed into the format of "flow maps."

Basically, the flow map is constructed by entering the statements in sequence proposed by the learner. The sequence of discourse is examined and recurrent ideas represented by recurring word elements in each statement (presenting a connecting node to a prior idea) are linked by connecting arrows. Moreover, recurrent arrows are inserted that link revisited ideas to the earliest step where the related idea first occurred. Figure 1 shows a student's flow map about nuclear power.

Students' recall of information analyzed through the flow map method could provide the following two quantitative variables representing their cognitive structures (Tsai 2001):

(1) ***Extent***: the total number of ideas in the learner's flow map.
(2) ***Richness***: the total number of recurrent linkages in the learner's flow map.

To acquire a deeper understanding about an individual student's usage of different information processing modes, the information processing modes shown in the flow maps were also investigated through a series of content analysis. Each of the student's statements,

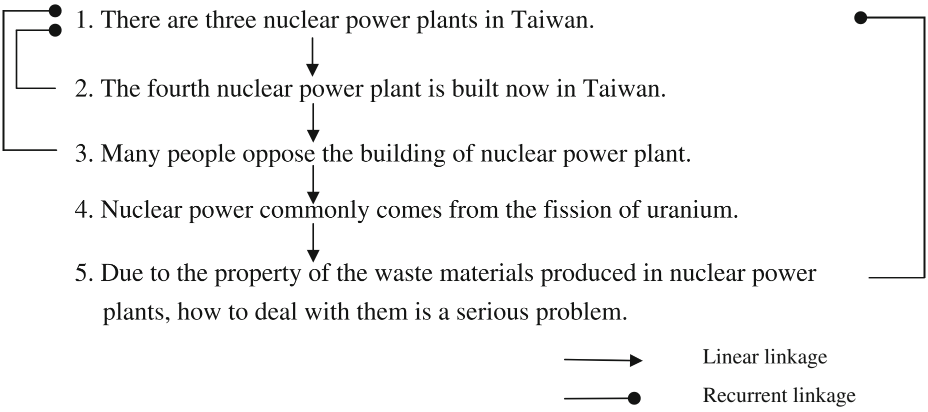

Fig. 1 A student's flow map about nuclear power. The student's narrative shows a sequential pattern beginning with the nuclear power plants in Taiwan to the basic rationale of nuclear power. The student also stated that the waste materials produced in nuclear power plants. Moreover, recurrent arrows are inserted that link revisited ideas to the earliest step where the related idea first occurred. Statement 2, for example, "The forth nuclear power plant is built now in Taiwan", includes one major revisited idea "nuclear power plant". Therefore, statement 2 has one recurrent arrow drawn back to the statement 1 (i.e., "There are three nuclear power plants in Taiwan."). The "extent" of the student's cognitive structure (i.e., the total number of ideas in the learner's flow map) is "5", and the "richness" of the student's cognitive structure (i.e., the total number of recurrent linkages) is "3"

shown in the flow maps, was categorized into one of the following four levels of information processing modes (from low to high) (Tsai 1999; Wu and Tsai 2005b):

(1) ***Defining***: Providing a definition of a concept or a scientific term, e.g., "Nuclear power is a form of energy produced by an atomic reaction."
(2) ***Describing***: Depicting a phenomenon or a fact, e.g., "There are three nuclear power plants in Taiwan."
(3) ***Comparing***: Stating the relationships between (or among) subjects, things, or methods, e.g., "Compared with thermal power, nuclear power can generate electric power more effectively."
(4) ***Inferring or Explaining***: Describing what will happen under certain conditions or offering an account to justify the causality of two facts or events, e.g., "Due to the property of the waste materials produced in nuclear power plants, how to deal with them is a serious problem".

As Wu and Tsai (2005a), the two information processing modes, "defining" and "describing" were viewed as lower-level modes of information processing, while the other two information processing modes (i.e., "comparing" and "inferring or explaining") were viewed as higher-level modes of information processing in this study. Students who frequently used higher-order modes of information processing (i.e., "comparing" and "inferring or explaining") were viewed as having better strategies for organizing information during recall.

In this study, an independent researcher was asked to transcribe a total of ten students' narratives into flow maps. The inter-coder agreement for sequential linkages of the flow map was 0.92, while the inter-coder agreement of recurrent linkages was 0.90. Similarly, the inter-coder reliability for the content analysis of information processing modes in each unit was also obtained in this study. The percentage that two researchers coded the students' ideas into the same category of information processing modes was 94%.

2. *Evaluating students' informal reasoning regarding nuclear power usage*

Wu and Tsai (2007) have developed an open-questionnaire for assessing learners' informal reasoning on nuclear power usage. In this study, the open-ended questionnaire developed by Wu and Tsai (2007) was slightly modified and used to collect the data regarding students' informal reasoning on nuclear energy usage. The participants were asked to write down their answers about the following questions:

(1) Do you agree with the building of the fourth nuclear power plant in Taiwan? Why? (assessing students' position on this issue)
(2) If you want to convince your friend with your position, what arguments you will propose to convince him/her? (evaluating students' ability to generate supportive arguments)
(3) If someone holds an opposite position with you on this issue, what arguments he/she may have? (assessing students' counter-argument construction)
(4) According to the arguments you have proposed in question 3, can you write down your opposing ideas to justify your position? (evaluating students' rebuttal construction)

After data collection, each of an individual student's arguments shown in his/her responses to the aforementioned open-ended questions were analyzed both qualitatively and quantitatively with the framework slightly modified from that of Wu and Tsai (2007) (for a detailed description, please refer to Wu and Tsai 2010). The framework used in this study includes several qualitative indicators (i.e., reasoning mode, and reasoning quality) and quantitative measures (i.e., number of reasoning modes, number of supportive arguments, number of counterarguments, number of rebuttals, and total number of arguments).

A detailed description of these indicators and measures in this study is as follows:

(1) **Qualitative indicators:** Three qualitative indicators were used for assessing students' informal reasoning on nuclear power usage, including:

    a. Reasoning quality: In this study, a student's reasoning quality was categorized as "lower-level" if he (or she) only made simple claims (supportive arguments) or counterarguments, while his (or her) reasoning quality was categorized as "higher-level" if he (or she) generated not only simple claims (supportive arguments) and counterarguments, but also rebuttals.
    b. Reasoning mode revealed in an argument: Learners may generate their arguments from different aspects, such as "social-oriented", "ecology-oriented", "economic-oriented", and "science or technology-oriented" perspectives. In this study, each argument proposed by the participants was categorized into one of the aforementioned reasoning modes.

(2) **Quantitative measures:** After qualitative analyses, the following quantitative measures were also obtained for representing students' informal reasoning on nuclear power usage:

    a. Number of supportive arguments: The amount of supportive arguments a learner constructs. The more the supportive arguments a learner proposed, the more he (or she) was able to provide supportive evidences for his/her position.

b. Number of counterarguments: The amount of counterarguments a learner proposes. This measure assessed the ability of a learner to reason from the counter-position.
c. Number of rebuttals: The amount of rebuttals a learner generated. The more the rebuttals a learner constructed, the more he (or she) was able to justify for his position.
d. Total number of arguments: The total amount of the three kinds of arguments above (i.e., supportive arguments, counterarguments, and rebuttals). This measure evaluated an individual learner's ability to make arguments regarding a socio-scientific issue.
e. Total number of reasoning modes: The total number of reasoning modes an individual utilized in his/her informal reasoning. Similar to the work by Wu and Tsai (2007), each argument proposed by an individual student in this study was categorized into one of the following four reasoning modes: social-oriented arguments, ecology-oriented arguments, economic-oriented arguments, and science or technology-oriented arguments. Then, the total number of reasoning modes an individual used was calculated. The more the total number of reasoning modes an individual learner used, the more he (or she) was oriented to reason from multiple perspectives. For example, when reasoning on a socio-scientific issue, if an individual proposed one socio-oriented argument and two economic-oriented arguments, he (or she) would be viewed as using two reasoning modes.

To assess the reliability of the aforementioned analyses, another researcher was asked to analyze 15 students' responses on an open-end questionnaire independently, and their inter-coder agreements for these analyses were assessed. All the inter-coder agreements for the analyses were greater than 0.80, indicating that the qualitative analyses of students' informal reasoning in this study were sufficiently reliable. Besides, the discrepancies were discussed, and final agreements were achieved.

Results

The Effects of Different On-line Searching Tasks on the Students' Cognitive Structure Outcomes

The mean and standard deviations (S.D.) for the students' cognitive structure outcomes regarding nuclear power usage before and after the conduct of on-line searching tasks are revealed in Table 1.

In this study, one-way ANCOVA was used to examine whether any significant difference existed in the two groups of students' cognitive structure outcomes after completing the on-line searching tasks. The students' cognitive structure outcomes before the conduct of the searching tasks were used as the covariates; and the students' cognitive structure outcomes after the conduct of the searching tasks were used the dependent variables. The adjusted mean and standard error for the two groups of students' cognitive structure outcomes after completing the searching tasks are shown in Table 2.

The results of ANCOVA, as shown in Table 2, revealed that the students in the guided on-line searching task group significantly outperformed their counterparts in the extent (F= 13.93, p<0.01) and the richness of their cognitive structures (F=9.12, p<0.01). Also, they significantly outperformed their counterparts in the usage of the two information processing strategies, "comparing" (F=4.40, p<0.05) and "inferring or explaining" (F=6.45, p<0.05).

Table 1 Students' cognitive structure outcomes about nuclear power usage before and after the conduct of on-line searching tasks (n=68)

		Before on-line searching tasks		After on-line searching tasks	
		Mean	S.D.	Mean	S.D.
Extent	Guided on-line searching group (n=33)	2.73	1.40	4.61	3.02
	Unguided on-line searching group (n=35)	2.97	1.77	3.17	1.52
Richness	Guided on-line searching group (n=33)	1.27	1.49	2.79	2.47
	Unguided on-line searching group (n=35)	1.40	1.67	1.49	1.63
Describing	Guided on-line searching group (n=33)	1.58	1.00	2.42	1.89
	Unguided on-line searching group (n=35)	2.06	1.14	2.09	1.20
Comparing	Guided on-line searching group (n=33)	0.45	0.56	1.24	1.37
	Unguided on-line searching group (n=35)	0.37	0.69	0.66	0.80
Inferring or Explaining	Guided on-line searching group (n=33)	0.70	0.88	0.88	0.86
	Unguided on-line searching group (n=35)	0.57	0.95	0.40	0.65

As aforementioned, students who frequently used higher-order modes of information processing (i.e., "comparing" and "inferring or explaining") were viewed as having better strategies for organizing information during recall (Tsai 2001; Wu and Tsai 2005a). The findings above imply that, compared with the unguided on-line searching task, the guided on-line searching task significantly helped students obtain more extended and more integrated cognitive structures regarding a socio-scientific issue as well as facilitate their usage of better information processing strategies.

The Effects of Different On-line Searching Tasks on the Students' Informal Reasoning Outcomes

In this study, how different on-line searching tasks contributed to the students' informal reasoning on nuclear power usage was further examined. Table 3 presents the mean and

Table 2 The ANCOVA adjusted means and standard error of variables of students' cognitive structure outcomes and the results of ANCOVA (n=68)

		Mean (adjusted)	Standard error	F-value
Extent	Guided on-line searching group (n=33)	4.73	0.32	13.93**
	Unguided on-line searching group (n=35)	3.06	0.31	
Richness	Guided on-line searching group (n=33)	2.83	0.33	9.12**
	Unguided on-line searching group (n=35)	1.45	0.32	
Describing	Guided on-line searching group (n=33)	2.42	0.27	0.79
	Unguided on-line searching group (n=35)	2.09	0.27	
Comparing	Guided on-line searching group (n=33)	1.21	0.18	4.40*
	Unguided on-line searching group (n=35)	0.68	0.18	
Inferring or explaining	Guided on-line searching group (n=33)	0.86	0.13	6.45*
	Unguided on-line searching group (n=35)	0.42	0.12	

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

Table 3 Students' informal reasoning outcomes regarding nuclear power usage before and after the conduct of on-line searching tasks (n=68)

		Before on-line searching tasks		After on-line searching tasks	
		Mean	S.D.	Mean	S.D.
Supportive argument	Guided on-line searching group (n=33)	1.27	0.67	1.27	0.52
	Unguided on-line searching group (n=35)	1.23	0.43	1.06	0.34
Counter-argument	Guided on-line searching group (n=33)	1.33	0.69	1.27	0.52
	Unguided on-line searching group (n=35)	1.49	0.61	1.14	0.49
Rebuttal	Guided on-line searching group (n=33)	0.39	0.50	0.42	0.56
	Unguided on-line searching group (n=35)	0.60	0.78	0.37	0.78
Total number of arguments	Guided on-line searching group (n=33)	2.67	1.11	2.97	1.10
	Unguided on-line searching group (n=35)	3.03	1.12	2.57	1.07
Total number of reasoning modes	Guided on-line searching group (n=33)	2.12	0.65	2.27	0.63
	Unguided on-line searching group (n=35)	2.29	0.57	1.97	0.66

standard deviations (S.D.) for the students' informal reasoning outcomes regarding nuclear power usage before and after the conduct of on-line searching tasks.

Similarly, one-way ANCOVA tests were also conducted to examine whether any significant difference existed in the two groups of students' informal reasoning outcomes after completing the on-line searching tasks. The students' informal reasoning outcomes before the searching tasks were conducted were used as the covariates; and the students' informal reasoning outcomes after the searching tasks were conducted used the dependent variables. The adjusted mean and standard error for the two groups of students' informal reasoning outcomes after completing the searching tasks are shown in Table 4.

The results in Table 4 showed that the students in the guided on-line searching task group only outperformed their counterparts in their supportive argument construction (F= 4.11, p<0.05). That is, the guided on-line searching task only helped the students propose

Table 4 The ANCOVA adjusted means and standard error of variables of students' informal reasoning outcomes and the results of ANCOVA (n=68)

		Mean (adjusted)	Standard error	F-value
Supportive argument	Guided on-line searching group (n=33)	1.27	0.08	4.11*
	Unguided on-line searching group (n=35)	1.06	0.07	
Counter-argument	Guided on-line searching group (n=33)	1.29	0.09	2.00
	Unguided on-line searching group (n=35)	1.12	0.09	
Rebuttal	Guided on-line searching group (n=33)	0.44	0.10	0.42
	Unguided on-line searching group (n=35)	0.34	0.10	
Total number of arguments	Guided on-line searching group (n=33)	3.01	0.19	3.26
	Unguided on-line searching group (n=35)	2.54	0.18	
Total number of reasoning modes	Guided on-line searching group (n=33)	2.28	0.11	3.78
	Unguided on-line searching group (n=35)	1.97	0.11	

*p<.05

significantly more supportive arguments, rather than rebuttals. In other words, the guided searching tasks did help the students obtain better cognitive structure outcomes; however, the increments on their cognitive structure outcomes may only help them to propose more supportive arguments, but their rebuttal construction was not particularly improved. It implies that learners' rebuttal construction, which is regarded as an important indicator for higher-quality reasoning, is not easily facilitated with a short period of on-line searching tasks.

Discussion

This study aimed to examine the effects of two different on-line searching tasks on students' cognitive structure outcomes and informal reasoning outcomes. It was found that the students in the guided on-line searching task group significantly outperformed the unguided on-line searching group in the extent and the richness of their cognitive structures as well as their usage of higher-order modes of information processing (i.e., "comparing" and "inferring or explaining"), suggesting guided on-line searching activities are useful for promoting student conceptual understanding regarding a specific topic. Findings derived from many previous studies have revealed the effectiveness of direct (or guided) instruction (Kirschner et al. 2006). The findings derived from this study concurred with those of previous studies. In a previous study, "process worksheets" were used as a means to guide instruction (e.g., Nadolski et al. 2005). Such worksheets provided a description of the phases one should go through when solving the problem as well as hints that may help to successfully complete the learning task. The usefulness of process worksheets has also been reported (e.g., Nadolski et al. 2005). In fact, the worksheet used in this study was somewhat different from the "process worksheets" in relevant studies. As aforementioned, the "process worksheets" provide guidelines for the procedures for solving problems in learning tasks, while the worksheet used in the present study guides the students to search relevant information from different perspectives. However, from the perspective of cognitive load theory, it seems that the use of a worksheet in this study reduced students' irrelevant cognitive load (i.e., extraneous load) and helped them put their working memory to work with a relevant cognitive load (i.e., germane load). As a result, the students in the guided group obtained better conceptual learning outcomes than their counterparts. In other words, the worksheet used in this study might also function as the process worksheets used in relevant studies.

Learners' application of learned knowledge in novel contexts (i.e., the transfer of learning) is always an important issue for educators (e.g., Haskell 2001). Evidence derived from previous studies exists for the benefits of both discovery learning and guided learning in transfer of learning (Rittle-Johnson 2006). In particular, some previous studies designed according to the perspectives of cognitive load theory have revealed the effectiveness of guided instruction in the transfer of learning (e.g., Klahr and Nigam 2004; van Merrienboer et al. 2002). In the current study, the effects of different on-line searching activities on learners' transfer of learning (i.e., their informal reasoning on a relevant socio-scientific issue) were also compared. It was revealed that the students benefited more from the guided on-line searching task on their supportive argument construction, while the students' rebuttal construction did not particularly improve after completing the guided on-line searching task. Kuhn (1993) has argued that rebuttals are critical because they complete the structure of argument, integrating argument and counterargument. It seems that, compared with un-guided instruction, the guided instruction in this study did help the student transfer their learning outcomes to complete a novel task with lower-level complexity (i.e., supportive argument construction);

however, the guided instruction did not help the students transfer their learning outcomes to complete a much more complex novel task (i.e., rebuttal construction). In other words, guided instruction may benefit learners in their transfer of lower-level reasoning skills, rather than complex reasoning skills, with a short-term duration. It seems that learners' rebuttal construction, which is regarded as an important indicator for higher-quality reasoning, is not easily facilitated with such a short period for the on-line searching task as conducted in this study. Besides, one may also be interested in the retention of the on-line searching skills derived from guided instruction (i.e., the transfer of the on-line searching skills in online searching tasks without the searching guideline provided in this study). Further research is suggested to address the aforementioned issue.

Moreover, it should also be acknowledged that although the students in the guided on-line searching group obtained relatively better cognitive structure outcomes they were not able to apply these newly-acquired concepts or ideas to improve their reasoning quality immediately after the conduct of the searching tasks. Science educators should pay more attention to how to facilitate learners' ability to apply what they have searched on the Internet to facilitate the quality of their informal reasoning regarding a socio-scientific issue.

This study attempts to address how to improve the quality of students' informal reasoning regarding a socio-scientific issue with the Internet. The findings in this study may inform researchers in terms of the effects of different on-line searching activities (i.e., guided instruction vs. unguided instruction) on students' cognitive structures and informal reasoning regarding a socio-scientific issue. However, it should be noticed that, with statistical analyses, this study may provide some initial evidence for the effects of different on-line searching activities on high school students' cognitive structures and informal reasoning regarding a socio-scientific issue. The conduct of qualitative studies addressing this issue will be helpful to provide different insights into this issue. Therefore, qualitative studies addressing this issue are suggested. Besides, the duration of the treatments in this study was only about two lessons (100 min). Therefore, interpreting the findings in this study should be treated carefully. Further research is also suggested for examining the efficiency of long-term guided on-line instruction, in particular the effects of guided instruction on the transfer of learning. The learning task in this study was a student self-directed learning task. Some pedagogical strategies suggested by teachers, coupled with the task, may be more helpful. For example, teachers may ask students to recall how they search on the Internet, judge the usefulness and correctness of on-line information, and integrate what they have searched on the Internet. Then, teachers may discuss the aforementioned issues with students and try to guide them to develop better searching and learning strategies in Internet-based learning environments.

Moreover, to get deeper insights into this issue, further research will be needed. For example, how learners' scientific epistemological beliefs interact with different on-line searching activities on their reasoning outcomes regarding a socio-scientific issue may also be another important issue for researchers. "Scientific epistemological beliefs" (SEBs) refers to beliefs about the nature of scientific knowledge and beliefs about the nature of knowing science (Hofer and Pintrich 1997). Recently, how learners' epistemological beliefs influence their Internet-based learning has received increasing attention among educational researchers. Tsai (2001) also advocated that learners' epistemological commitments would guide their metacognition and critical thinking in Internet-assisted science classrooms. Similarly, Hofer (2004) suggested that students' awareness in their epistemological judgments could enhance their ability to think critically about seeking and evaluating information on the Internet. From the perspectives above, learners' epistemological beliefs may influence their ways of seeking and evaluating information regarding a socio-scientific issue on the Internet, and, then, affect the reconstruction of their conceptual understanding and reasoning regarding this issue. However, still not much research has addressed how learners' scientific epistemological beliefs interact with different on-line searching activities on their learning outcomes regarding a socio-scientific issue, in particular on their informal reasoning outcomes. Further research is also suggested to address the aforementioned issue.

The current study also provides some implications for the practice of science education. For example, the usefulness of a guided on-line searching activity on promoting students' conceptual understanding regarding a socio-scientific issue is revealed. It suggests that, in Internet-based science learning environments, the guidance from teachers is needed to focus students to address the task. Moreover, it was revealed in this study that learners' reasoning quality regarding a socio-scientific issue is not easily facilitated. Zohar and Nemet (2002) have reported the effectiveness of the integration of explicit teaching of reasoning patterns in lessons for improving students' argumentation quality. To improve students' reasoning quality, explicit instruction regarding informal reasoning and long-term SSI-based learning activities may be helpful.

Conclusions

Improving learners' ability to deal with socio-scientific issues has been highlighted in contemporary science education. (e.g., AAAS 1989, 1993). To address this issue, the current study explored the effects of different on-line searching activities on high school students' cognitive structure outcomes and informal reasoning outcomes. This study revealed the usefulness of guided on-line searching activities on promoting student conceptual understanding regarding a specific topic. However, the increments on the students' cognitive structure outcomes only helped them to propose more supportive arguments, but their informal reasoning quality was not improved. It seems that learners' transfer of higher-level reasoning skills, such as informal reasoning skills, is not easily facilitated with such a short period of an on-line self-directed searching task as conducted in this study. Pedagogical innovations of this sort and long-term instruction may be helpful to improve students' informal reasoning regarding socio-scientific issues.

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