Learner-Adaptable Scaffolding with Cognitive Tool for Developing Self-Regulation Skill

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Abstract: Self-regulation plays a crucial role in promoting efficiency and effects of self-directed learning process. The main issue addressed in this paper is how to develop the self-regulation skill. This paper describes a cognitive apprenticeship approach to this issue, which enables learners to accumulate experiences of self-regulation process with cognitive tool. In particular, we propose a learner-adaptable scaffolding method, in which functions of the tool can be fadable according to their self-regulation skill. This paper also demonstrates the learner-adaptable scaffolding with Interactive History that is a cognitive tool helping learners accomplish self-regulation process necessary for Web-based navigational learning. The results of the case study suggest that it allows learners to fade functions of the cognitive tool to develop their self-regulation skill.

Keywords: Fadable scaffolding, cognitive tool, self-regulation skill, navigational learning

Introduction

The emergence of the Web brings about a lot of opportunities for learners to learn in a self-directed way. Self-directed learning requires them to regulate their learning process by themselves for achieving their own goals. Such self-regulation process can be viewed as meta-cognitive one [1], which is a key to succeeding in self-directed learning.

On the other hand, it is not so easy for learners to self-regulate the learning process since the target of self-regulation is learning process in their mind [10]. In self-directed learning with resource providing hyperspace, for example, the learners often get lost in the hyperspace spatially and conceptually since they have difficulties in monitoring and controlling their navigation and knowledge construction process in their mind [11].

How to develop self-regulation skill has become an important issue in research concerning self-directed learning [10]. In order to develop it, it is necessary for learners to have and accumulate cognitive experiences of self-regulation process. We have accordingly introduced cognitive tool [6]. Cognitive tool is a computational tool, which enables learners to externalize the learning process to articulate their learning process [8]. Such articulation could reduce difficulty of self-regulation process. We also expect that cognitive tool could allow them to reify the self-regulation process by making the learning process represented on the tool operable and controllable. Such reification enables the learners to have their experience of self-regulation process.

Related work on self-regulation skill development has mainly focused on instructions for learners to master strategies of self-regulation [7]. However, there is little discussion about how to help learners accumulate their cognitive experiences of self-regulation with software-based learning technology.

The main issue addressed in this paper is how to develop self-regulation skill with cognitive tool. Our approach to this issue is to follow cognitive apprenticeship [2], which suggests how to accumulate experiences of self-regulation process. Cognitive apprenticeship provides a methodology for acquiring cognitive skill through six phases of learning or teaching how to accomplish cognitive process: *Modeling*, *Coaching*, *Scaffolding*, *Articulation*, *Reflection*, and *Exploration* [2]. In order to apply it to self-regulation skill development, we need to model the self-regulation process and to enable learners to experience it with cognitive tool [6].

This paper deals with self-regulation in self-directed learning with Web resources, and presents a cognitive apprenticeship framework with Interactive History (IH for short) as cognitive tool we have implemented for reifying self-regulation of the Web-based learning process [5]. In particular, this paper focuses on the scaffolding phase in the cognitive apprenticeship, and proposes a learner-adaptable scaffolding method, in which functions of IH can be fadable according to their self-regulation skill. This paper also describes a case study whose purpose was to ascertain whether the learner-adaptable scaffolding could work well. The results suggest that learners can fade IH functions to develop their self-regulation skill in an adaptable way.

1. Cognitive Apprenticeship Framework

1.1 Cognitive Apprenticeship

Cognitive apprenticeship is a social constructivism theory for learning, and provides a methodology for acquiring cognitive skill through the six phases of learning or teaching how to accomplish cognitive process [2]. The purpose of each phase is as follows:

Modeling: to allow learners to know/gain a model of learning process to be learned,
Coaching: to coach them so that they can accomplish learning process as modeled,
Scaffolding: to construct fadable scaffolds for the learning process accomplishment,
Articulation: to allow them to articulate their learning process accomplished,
Reflection: to allow them to reflect on their learning process accomplished, and
Exploration: to allow them to accomplish the learning process in various contexts.

In order to apply such phases to meta-cognitive skill development, we have modeled self-regulation process in learning with Web resources, and have introduced IH that enables learners to reify the self-regulation process.

1.2 Navigational Learning and Self-Regulation Process

In hyperspace provided by Web resources learners can navigate the Web pages with a learning goal in a self-directed way. The self-directed navigation involves constructing knowledge, in which they would make semantic relationships among the contents learned at the navigated pages [3]. Such navigation with knowledge construction is called navigational learning [5]. In the learning process, the movement between various pages is often driven by a local goal called navigation goal to search for the page that fulfills it. Such navigation goal is regarded as a sub goal of the learning goal. The navigational learning process includes producing and achieving a number of navigation goals.

We currently classify navigation goals into six: *Supplement*, *Elaborate*, *Compare*, *Justify*, *Rethink*, and *Apply*. For instance, a learner may search for the meaning of an unknown term to supplement what he/she has learned at the current page. We refer to the

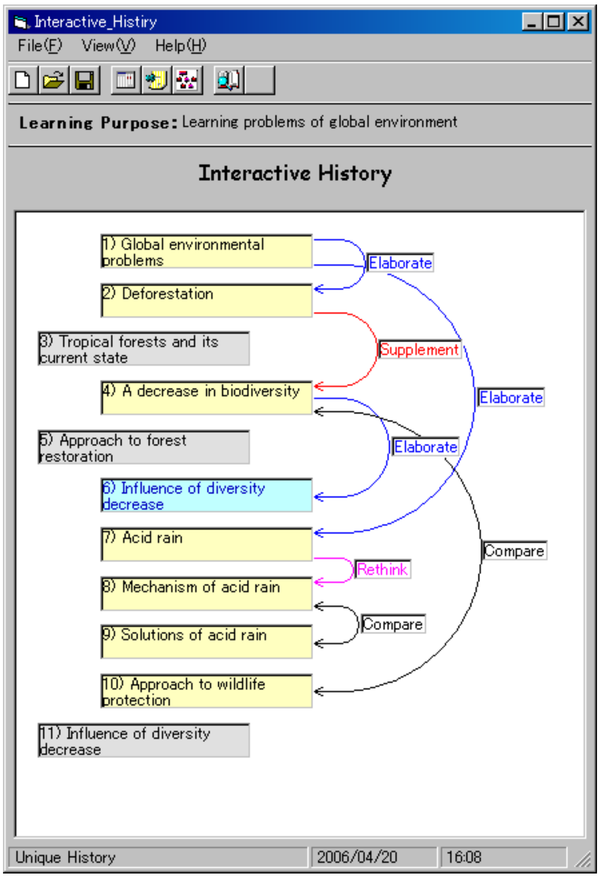

Figure 1. Annotated Navigation History.

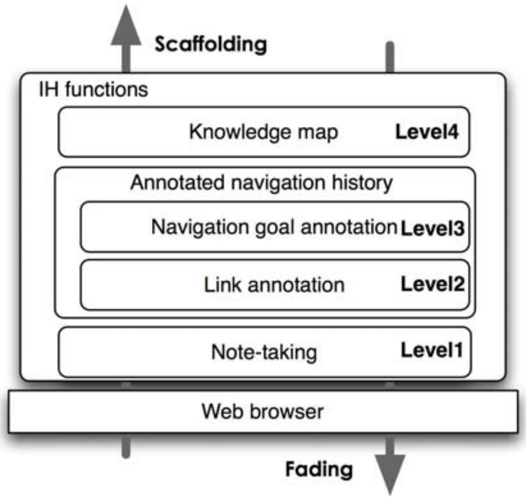

Figure 2. Scaffolding Levels in IH.

process of fulfilling a navigation goal as primary navigation process [5]. This is represented as a link from the starting page where the navigation goal arises to the terminal page where it is fulfilled.

The knowledge construction process can be modeled as a number of primary navigation processes [5]. In each primary navigation process, learners would integrate the contents learned at the starting and terminal pages. They would then construct knowledge from the integrated contents.

On the other hand, the learners are required not only to navigate the pages to construct knowledge, but also to reflect on and reconstruct their own navigational learning processes [5],[11]. Such reflection and reconstruction process corresponds to self-regulation one, which can be divided into the following three sub-processes in accordance with the knowledge construction model:

(a) Reflection on and re-learning the contents learned at starting and terminal pages,
(b) Reflection on and reconstruction of primary navigation processes, and
(c) Reflection on and reconstruction of relationships among the processes.

1.3 Interactive History

In order to scaffold the self-regulation process, IH provides learners with three functions: annotated navigation history, note-taking, and knowledge map. These functions enable learners to reify the self-regulation sub-processes described in 1.2.

Figure 1 shows an example of annotated navigation history. IH monitors learners' navigation in the Web browser to generate a navigation history, which includes the pages sequenced in order of time they have visited, in the *Annotated Navigation History* window. The learners can annotate the navigation history with the primary navigation processes, which they have carried out. Such annotation includes linking the starting and terminal pages (link annotation) and attaching the navigation goal to the link (navigation goal annotation). They can also reconstruct their navigational learning process by deleting/modifying/adding the annotated primary navigation processes.

The learners can also take a note about the contents learned at the starting or terminal pages. The note is linked to the page in the annotated navigation history. The learners can reflect on and delete/modify the note on their demand.

When the annotated navigation history includes more primary navigation processes, the learners have more difficulty in understanding the relationships among them. IH accordingly generates a knowledge map by transforming primary navigation processes into visual representation. (See [5] for detailed generation mechanism.)

The results of the case study, which we have had with IH, suggest that it is very useful for experiencing self-regulation in navigational learning process [5]. In order to develop the self-regulation skill, however, it is necessary not only to experience the self-regulation process with IH but also to accumulate the cognitive experiences.

1.4 Self-Regulation Skill Development

Let us here present the cognitive apprenticeship framework for developing the self-regulation skill with IH. In the modeling phase, we can provide learners with IH demonstrations and some explanations about knowledge construction with primary navigation processes and about operations for reflecting on and reconstructing the knowledge construction process. Such support would be quite instructive for learners to understand the model of self-regulation process defined in IH [4]. In the coaching phase, learners are allowed to use IH for learning Web resources with instructions of IH operations.

In the scaffolding phase, we will provide learners with a learner-adaptable scaffolding method, in which functions of IH can be fadable according to their self-regulation skill. The purpose is to induce them to gradually accomplish the self-regulation sub-processes by themselves without IH functions.

In the articulation and reflection phases, IH allows learners to articulate and reflect on their navigational learning process. The important point in such phases is to enable them to self-assess their self-regulation process. However, it is hard to self-assess if it is good or bad. We have accordingly developed ihComparator, with which the learners can compare their own self-regulation process with other learners' ones by means of comparison between the navigational learning histories generated from IH [9].

In the exploration phase, we would provide learners with various Web resources and other cognitive tools, and ask them to accomplish the self-regulation process in these contexts. How to sequence these Web resources would be an important topic in this phase.

2. Learner-Adaptable Scaffolding

In the learner-adaptable scaffolding method, the number of IH functions available for learners is regarded as scaffolding level. This method fades IH functions available to decrease the scaffold level. This intends to induce the learners to think how the self-regulation process corresponding to the function faded could be accomplished in their mind, which would contribute to developing the self-regulation skill.

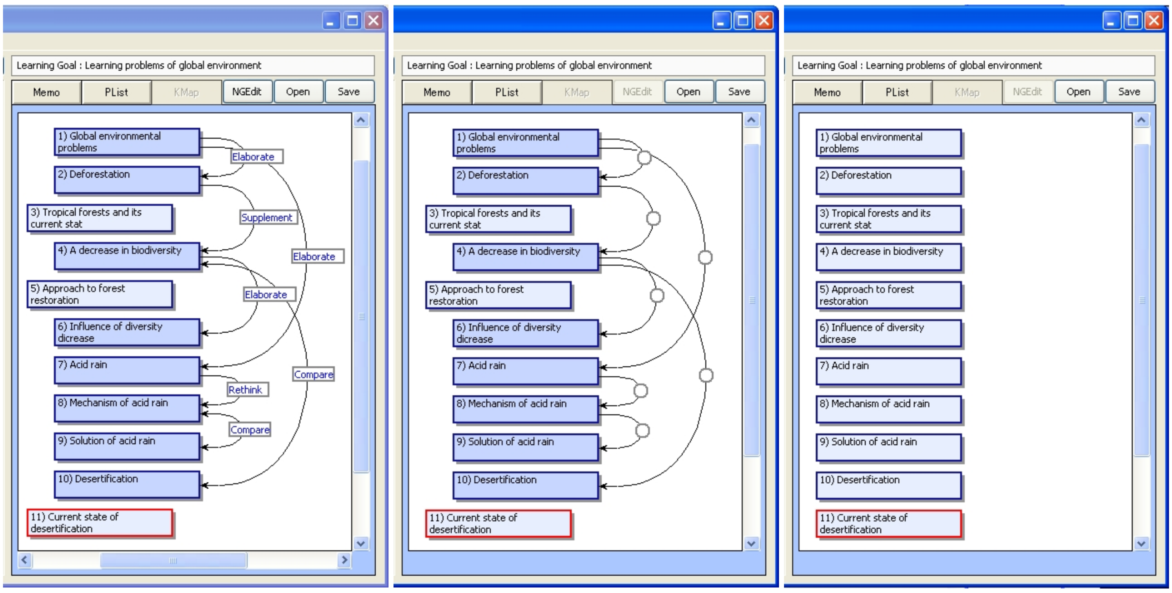

Figure 3. Example of Learner-Adaptable Scaffolding.

When the learners get stuck in the self-regulation process in their mind, the functions fade in once again. They are then expected to reconfirm significance and value of the functions. Such reconfirmation induces them to gain deeper understanding of the function to develop the skill of using IH, which would be also indispensable for developing the self-regulation skill.

The final goal of this method is to enable the learners to monitor and reconstruct their navigational learning process in their mind only with Web browser (without IH). Skillful learners could carry out the self-regulation process without operating IH functions and regardless of learning tools. This method also follows a learner-adaptable approach, in which learners could control the scaffolding level by themselves in accordance with their self-regulation skill.

Figure 2 shows the order of fading or scaffolding IH functions. In the initial stage, learners use full functions of IH to accumulate experiences of self-regulating navigational learning process. IH functions then fade out from the upper one shown in Figure 2. Knowledge map function first fades out, and then the remaining functions fade out in the order of navigation goal annotation, link annotation, and note-taking. When learners start learning with a Web resource, they can decide IH functions available by adjusting the scaffolding level. If they need the function faded during navigational learning process, they can make it available once again.

Figure 3 shows an example of fading IH functions. The left window demonstrates the scaffolding level 3 where knowledge map fades out. The middle and right window also demonstrate the scaffolding level 2 and 1 where navigation goal annotation fades out, and where annotated navigation history (navigation goal and link annotations) fades out.

In decreasing the scaffolding level 3 to 2, the learner is expected to carry out the navigation goal annotation in his/her mind. In decreasing the scaffolding level 2 to 1, he/she is also expected to carry out primary navigation processes in his/her mind. In this way, self-regulation process in mind increases when the scaffolding level decreases. This intends to develop self-regulation skill.

3. Case Study

3.1 Preparation and Procedure

In order to ascertain whether the learner-adaptable scaffolding could develop self-regulation skill in navigational learning, we have conducted a case study as follows.

We prepared 18 sessions for eleven days over three weeks, in which subjects learned 14 resources (The number of pages included in each resource was from 43 to 134, and the average number of links except navigation links such as *back*, *home* and *next* per page was from 2.2 to 5.7.) with learner-adaptable scaffolding. Before starting the first session, we required each subject to adjust the scaffolding level in IH according to his/her own self-regulation skill and to aim at fading all functions of IH to learn only with Web browser. In the first session, full functions of IH were provided. In the succeeding sessions, he/she was allowed to adjust the scaffolding level. During each session, he/she was not allowed to change the scaffolding level. We provided unique learning goal every session.

We also prepared pre-session and post-session before and after the 18 sessions. In the pre and post sessions, we required each subject to learn the two same resources whose domains were (D1) circulatory and (D2) the Kamakura era (1192 to 1333 in Japan) only with Web browser. The resource D1 had simpler hyperspace (the number of pages included was 62, and the average number of links except navigation links per page was 5.1.). The resource D2 had more complicated hyperspace (the number of pages was 125, and the number of links except navigation links per page was 10.1). We ascertained whether self-regulation process worked well by analyzing the difference between histories obtained from navigational learning in the pre and post sessions.

Subjects were five graduate students in science and technology who had more than three years experience in Web use. In the pre-session, the time limit given for learning each resource (D1 and D2) was 30 minutes. After finishing learning the resource, he/she was then required to check pages that were instructive in achieving the learning goal from the navigation history generated with the Web browser. We call such pages learner-selected instructive pages.

He/she was then required to have two sessions per day. In each session, he/she was required to learn the resource with the learner-adaptable scaffolding for 20 to 30 minutes. Before starting learning, he/she adjusted the scaffolding level by referring to the annotated navigation history generated with IH in the previous session.

The post-session was conducted two days later from the final session. He/she was required to learn the resource D1 in the same way as the pre-session. After three days, he/she was then required to learn the resource D2 in the same way as the pre-session.

3.2 Results

All subjects could decrease and increase the scaffolding level, and then resulted in learning in the level 0 that means learning only with Web browser. This suggests that the learner-adaptable scaffolding allows learners to recognize their own regulation skill to decrease the scaffolding level. Although there is one subject who increased the scaffolding level from 0 to 4 in the session 17, we ascertained from the interview with him that he wanted to compare his self-regulation process in his mind with the one enabled by IH. Such comparison affords a piece of evidence that self-regulation skill has been developed.

In order to ascertain the self-regulation skill development, we compared learning history in the pre-session and the one in the post-session. In case self-regulation skill is improved, navigational learning process is expected to become convergent and goal-oriented. In other words, page revisit for reflection on and reconstruction of knowledge construction process in hyperspace would converge on restricted pages, and pages unrelated to learning goal achievement would not be visited for a long time nor be learned.

We used the following data to analyze the convergence and goal-orientedness of navigational learning process.

- **Visited pages**, which were visited more than once.
- **Learner-selected instructive pages**,
- **Instructive pages**, which were learner-selected instructive pages revisited, and
- **Learned pages**, which includes all learner-selected instructive pages, and which were visited for longer time than the average of each longest time in visiting (or revisiting) each learner-selected instructive page.

Table 1 shows the average data for analyzing the convergence (from data (1) to (4)) and goal-orientedness (from data (5) to (6)) of navigational learning process, which was obtained from navigation histories the five subjects generated in the pre and post sessions. From the result of t-test analysis with the data (3) and (4), there was a tendency towards significant difference between the ratios of the number of browsing instructive pages to the number of browsing visited pages in the pre-session and the ones in the post-session ($t_{(4)}$=2.44, p<.10 for D1; and $t_{(4)}$=2.58, p<.10 for D2). The post-sessions' ones were slightly higher than the pre-session's ones regardless of the learning resource. The ratios of the number of revisits to instructive pages to the number of revisits to visited pages in the post-session were also significantly higher than the ones in the pre-session ($t_{(4)}$=2.45, p<.10 for D1; and $t_{(4)}$=3.27, p<.05 for D2). From the fact that all subjects turned off the scaffolding provided by IH, these results suggest that navigational learning process becomes convergent after learner-adaptable scaffolding in the 18 sessions.

From the results of t-test analysis with the data (6), there was a significant difference between the ratios of the number of browsing learner-selected instructive pages to the number of browsing learned pages in the pre-session and the one in the post-session ($t_{(4)}$=3.31, p<.05 for D1; and $t_{(4)}$=2.46, p<.10 for D2). The post-sessions' ones were higher than the pre-session's ones regardless of the learning resources. This suggests that wasted efforts for learning the pages unrelated to learning goal achievement decrease after the learner-adaptable scaffolding.

From the above results, we can say that the learner-adaptable scaffolding induces learners to decrease the scaffolding level and to enhance the convergence and goal-orientedness of navigational learning process to develop their self-regulation skill.

Table 1. T-Test Analysis for Self-Regulation Process.

Data	Learning resources	Pre-session	Post-session
(1) The number of visited pages	D1 D2	35.8 29.4	35.6 23.2*
(2) The ratio of the number of instructive pages to the number of visited pages	D1 D2	0.31 0.31	0.48** 0.40
(3) The ratio of the number of browsing instructive pages to the number of browsing visited pages	D1 D2	0.52 0.60	0.70* 0.73*
(4) The ratio of the number of revisits to instructive pages to the number of revisits to visited pages	D1 D2	0.63 0.74	0.82* 0.88**
(5) The ratio of the number of learner-selected instructive pages to the number of learned pages	D1 D2	0.88 0.93	0.97* 0.97*
(6) The ratio of the number of browsing learner-selected instructive pages to the number of browsing learned pages	D1 D2	0.84 0.93	0.96** 0.98*

****: p<0.05, *: p<0.10**

4. Conclusion

This paper presents a cognitive apprenticeship framework for developing self-regulation skill as meta-cognitive one in Web-based navigational learning with cognitive tool called IH. This paper also proposes a promising method for learner-adaptable scaffolding, in which learners can adjust the scaffold level in accordance with their regulation skill. The purpose of the proposed method is to help learners acquire and develop the self-regulation skill with IH, and ultimately to induce them to carry out the self-regulation process in their mind without operating IH functions and regardless of learning tools.

This paper has also described a case study. The results indicate the possibility that the learner-adaptable scaffolding helps learners accumulate their experience of self-regulation process to develop their regulation skill.

In future, we will conduct more detailed evaluation to refine the learner-adaptable scaffolding, and plan to address learning technologies for other phases in the cognitive apprenticeship.

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